REPLACEMENT FUEL AND ALTERNATIVE FUEL VEHICLE

TECHNICAL AND POLICY ANALYSIS

Pursuant to Section 506

of the

Energy Policy Act of 1992

December 1999
(With amendments September 2000)

Energy Efficiency and Renewable Energy
Office of Transportation Technologies

FOR MORE INFORMATION

NATIONAL ALTERNATIVE FUELS HOTLINE AND DATA CENTER is a source for information on issues related to alternative transportation fuels.

1-800-423-1DOE (423-1363); on the World Wide Web: http://www.afdc.doe.gov

The **CLEAN CITIES HOTLINE** has information on issues related to the CLEAN CITIES Program.

1-800-CCITIES (224-8437); on the World Wide Web: http://www.ccities.doe.gov

EREC, the **ENERGY EFFICIENCY AND RENEWABLE ENERGY CLEARINGHOUSE,** provides phone, mail, and electronic responses to inquiries about the U.S. Department of Energy's alternative fuel transportation programs.

Phone: 1-800-DOE-EREC (363-3732)
TDD: 1-800-273-2957
Fax: 1-703-893-0400
Computer Bulletin Board: 1-800-273-2955
Internet Electronic Mail: energyinfo@delphi.com

EREN, the **ENERGY EFFICIENCY AND RENEWABLE ENERGY NETWORK,** provides users of the World Wide Web another gateway to information and resources:

http://www.eren.doe.gov

RELATED PUBLICATIONS

EPACT INITIATIVES FOR ALTERNATIVE FUEL VEHICLES, U.S. Department of Energy, Office of Transportation Technologies, March 1995.

ALTERNATIVE FUEL VEHICLES FOR STATE GOVERNMENT & FUEL PROVIDER FLEETS, (A Guide to 10 CFR Part 490), U.S. Department of Energy, Office of Transportation Technologies.

REPLACEMENT FUEL AND ALTERNATIVE FUEL VEHICLE TECHNICAL AND POLICY ANALYSIS, (Pursuant to section 506 of the Energy Policy Act), DRAFT (62 FR 55622, October 27, 1999), U.S. Department of Energy, Office of Transportation Technologies.

MARKET POTENTIAL AND IMPACTS OF ALTERNATIVE FUEL USE IN LIGHT-DUTY VEHICLES: A 2000/2010 ANALYSIS, Technical Report 14 in the Flexible and Alternative Fuel Series, U.S. Department of Energy, Office of Policy and Office of Energy Efficiency and Renewable Energy, January 1996.

ALTERNATIVE FUEL TRANSPORTATION PROGRAM, 10 CFR Part 490, *61 Federal Register 10622*, March 14, 1996.

ALTERNATIVES TO TRADITIONAL TRANSPORTATION FUELS 1997, U.S. Department of Energy, Energy Information Administration, Report DOE/EIA-0585(97).

ENERGY SECURITY - EVALUATING U.S. VULNERABILITY TO OIL SUPPLY DISRUPTIONS AND OPTIONS FOR MITIGATING THEIR EFFECTS, U.S. General Accounting Office, Report to the Chairman, Committee on the Budget, House of Representatives, Report GAO/RCED-97-6, December 1996.

THE END OF CHEAP OIL, Colin J. Campbell and Jean H. Leberrère, Scientific American, Volume 278, No. 3, March 1998.

THE OUTLOOK FOR US OIL DEPENDENCE, David L. Greene, Donald W. Jones, and Paul N. Leiby, *Energy Policy*, Vol. 26, No. 1, pp. 55-69, 1998.

25TH ANNIVERSARY OF THE 1973 OIL EMBARGO—ENERGY TRENDS SINCE THE FIRST MAJOR U.S. ENERGY CRISIS, September 17, 1998, U.S. Energy Information Administration, www.eia.doe.gov.

WHAT DOES THE KYOTO PROTOCOL MEAN TO U.S. ENERGY MARKET AND THE U.S. ECONOMY? U.S. Energy Information Administration Briefing Paper No. SR/OIAF/98-03 (S), October 1998.

TABLE OF CONTENTS

LIST OF ACRONYMS vi

PREFACE vii

Oil Price Addendum viii

I. CONCLUSIONS 1

II. SUMMARY OF FINDINGS 7
- Energy Security Concerns 7
- Progress Toward Achieving the Goals Described in Section 502(b)(2) 9
- Actual and Potential Role of Replacement Fuels and AFVs in Reducing Oil Imports 9
- Actual and Potential Availability of Replacement Fuels and AFVs 11
- Key Issues and Perspectives 12

III. INTRODUCTION 15
- Energy Security Concerns 15
- Importance of the Transportation Sector 19
- EPACT Title V 20

IV. PROGRESS MADE IN ACHIEVING THE GOALS DESCRIBED IN SECTION 502(b) 21
- Federal Fleet Program 21
  - Vehicle Acquisition Process 22
  - Funding History 23
- Clean Cities Program 23
  - Goals 24
  - Approach 24
  - Accomplishments 24
- EPACT Rulemaking Activities 25
  - Alternative Fuel Provider and State Fleet AFV Acquisition Requirements 25
  - State Grants 25
  - Private and Local Government Fleet AFV Acquisition Requirements (Early Schedule) 25
  - Private and Local Government Fleet AFV Acquisition Requirements (Late Schedule) 26
  - P-Series Fuel Alternative Fuel Designation 27
  - Biodiesel Fuel Use Credit 27
- EPACT Analytical and Informational Activities 27
  - Replacement Fuel Goals 27

Replacement Fuel Demand and Supply Program 28
Replacement Fuel Demand Estimates and Supply Information 29
DOE Research, Development, and Demonstration Programs 29
Advanced Vehicle Propulsion Technologies 29
Alternative Fuels Research, Development, and Demonstration 30
Coordination with EPA Program 31

V. ACTUAL AND POTENTIAL ROLE OF REPLACEMENT FUELS AND AFVs 33
Actual Role of Replacement Fuels and AFVs 33
Potential Role of Replacement Fuels and AFVs 35
Market Potential: Analytical Results to Date 35
Transition Analyses 39
Transitional Analysis Result Highlights 40
AFV Penetration Needed to Reach the 10 and 30 Percent Goals 41
Lessons from International Experience 49
Transition Scenarios and Necessary Measures 52

VI. ACTUAL AND POTENTIAL AVAILABILITY OF AFVs AND REPLACEMENT FUELS . . 55
Actual and Potential Availability of AFVs 56
Current AFV Technologies 56
Natural Gas 56
Liquefied Petroleum Gas 57
Methanol 58
Ethanol 58
Electricity 58
Potentially Available Technologies 59
Hybrid Electric Vehicles 59
Fuel Cell Vehicles 60
Hydrogen Vehicles 60
Availability by Vehicle Type 61
New AFV Passenger Cars 61
New AFV Light Trucks and Vans 62
Converted Vehicles 64
Actual and Potential Availability of Replacement Fuels 64
National Availability 64
Regional Availability 67
Availability of Refueling Sites 68
Methanol/Ethanol Stations 69
CNG Stations 71
LPG Stations 72
Electric Vehicle Recharging Stations 74

VII. KEY ISSUES AND PERSPECTIVES 75
Fleet to Household AFV Spillover 76
Fuel Neutrality of Policy Options 77
AFV Technology and EPACT Timetables 78

Macroeconomic Impacts 78
Impact of Oil Price Cycle on Transition to Alternative Fuels 79
Impact of EPACT on Potential Oil Crises 81

LIST OF ACRONYMS

AEO	Annual Energy Outlook
AF	alternative fuel
AFTM	Alternative Fuels Trade Model
AFV	alternative fuel vehicle
AMFA	Alternative Motor Fuels Act of 1988
bpd	barrels per day
Btu	British thermal unit
CAA	Clean Air Act
CNG	compressed natural gas
CO	carbon monoxide
CO_2	carbon dioxide
CRS	Congressional Research Service
DOD	Department of Defense
DOE	Department of Energy
DOT	Department of Transportation
E10	10 percent ethanol (90 percent gasoline)
E85	85 percent ethanol (15 percent gasoline)
ECRA	Energy Conservation Reauthorization Act of 1998
EIA	Energy Information Administration
EPA	Environmental Protection Agency
EPACT	Energy Policy Act of 1992
EV	electric vehicle
FFV	flexible fuel vehicle
FY	fiscal year
GHG	greenhouse gases
GM	General Motors
GNP	gross national product
GSA	General Services Administration
GVW	gross vehicle weight
HWOP	High World Oil Price
IPCC	Intergovernmental Panel on Climate Change
LDV	light-duty vehicle
LEV	low emissions vehicle
LNG	liquefied natural gas
LPG or LP gas	liquefied petroleum gas
MTBE	methyl tertiary butyl ether
M85	85 percent methanol (15 percent gasoline)
M100	100 percent methanol (“neat methanol”)
NAFTA	North American Free Trade Agreement
NGL	natural gas liquids
OEM	original equipment manufacturer
OPEC	Organization of Petroleum Exporting Countries
PNGV	Partnership for a New Generation of Vehicles
ppm	parts per million
psi	pounds per square inch
QVM	qualified vehicle modifier
R&D	research and development
RD&D	research, development and demonstration
SULEV	super ultra low emissions vehicle
TAFV	Transitional Alternative Fuel Vehicle
ULEV	ultra low emissions vehicle
USPS	U.S. Postal Service
ZEV	zero emissions vehicle

PREFACE

The Energy Policy Act of 1992, Pub. L. 102-486, (EPACT) includes section 506 entitled "TECHNICAL AND POLICY ANALYSIS." Section 506 provides as follows:

(a) REQUIREMENT--Not later than March 1, 1995, and March 1, 1997, the Secretary shall prepare and transmit to the President and the Congress a technical and policy analysis under this section. The Secretary shall utilize the analytical capability and authorities of the Energy Information Administration and such other offices of the Department of Energy as the Secretary considers appropriate.

(b) PURPOSES--The technical and policy analysis prepared under this section shall be based on the best available data and information obtainable by the Secretary under section 503, or otherwise, and on experience under this title and other provisions of law in the development and use of replacement fuels and alternative fueled vehicles, and shall evaluate--

(1) progress made in achieving the goals described in section 502(b)(2), as modified under section 504;

(2) the actual and potential role of replacement fuels and alternative fueled vehicles in significantly reducing United States reliance on imported oil to the extent of the goals referred to in paragraph (1); and

(3) the actual and potential availability of various domestic replacement fuels and dedicated vehicles and dual fueled vehicles.

(c) PUBLICATION--The Secretary shall publish a proposed version of each analysis under this section in the Federal Register for public comment before transmittal to the President and the Congress. Public comment received in response to such publication shall be preserved for use in rulemakings under section 507.

The replacement fuel goals referenced in section 506 and contained in section 502(b) are as follows:

(2) determine the technical and economic feasibility of achieving the goals of producing sufficient replacement fuels to replace, on an energy equivalent basis—

(A) at least 10 percent by the year 2000; and

(B) at least 30 percent by the year 2010,

of the projected consumption of motor fuel in the United States for each such year, with at least one half of such replacement fuels being domestic fuels.

This report represents a technical and policy analysis required by EPACT section 506. It addresses each of the elements that the statute called on the Department of Energy (DOE) to evaluate. Each of the three statutory elements, called for by section 506(b), is discussed in a separate section of the report (Sections IV, V, and VI) following the Executive Summary and the Introduction. In addition, DOE has chosen to identify and discuss some additional issues and perspectives not specifically suggested by the statute. These are included principally in Section VII of the report, entitled "Key Issues and Perspectives," although the Introduction (Section III) and the Conclusions section (Section I) also include some conceptual discussion. This report is based on data collected through the early part of 1999. An addendum has been added to address recent changes in petroleum prices.

Oil Price Addendum

This report represents the culmination of several years of observation and analysis. Reports of this type as a practical necessity cannot assimilate current events through the date of release. In the case of this report, the technical content is current as of fall 1999. Since that time, an event occurred that had not been observed for 10 years — crude oil prices have nearly tripled, rising from about $10 per barrel in January 1999 to around $30 per barrel in March 2000. This is just the sort of event acknowledged as being likely by this report, though no capability to predict such events is claimed. The following discusses how this recent change in events affects the conclusions of this report.

The recent rise in crude oil prices has been reflected in increases in the real price of gasoline and diesel fuel, with diesel prices rising the fastest and highest. These price hikes dramatically underscore the monetary impact of our reliance on oil in transportation. However, these increases in real prices are not likely, in and of themselves, to allow alternative fuel vehicles to compete economically except in selected niche markets. For example, although the gap has closed somewhat, the price of ethanol is still about 10% more expensive per gasoline gallon equivalent than gasoline. Many alternative fuel vehicles carry a higher initial cost, and the lack of refueling infrastructure cannot be solved overnight. Another consideration is that energy markets are interrelated, and the price of natural gas and propane has also risen recently, though only about half as much as oil. Thus, while the increase in crude oil prices does make alternative fuels more competitive, these recent increases have not been large enough, nor have they been sustained for a long enough period, for alternative fuels to overcome the transitional barriers to achieving wide-scale use.

Although the report's conclusion that the technical barriers to using alternative fuels are being overcome remains valid, it is unlikely, even with the recent oil price increases, that the Energy Policy Act (EPACT) 10 and 30 percent replacement fuel goals for the years 2000 and 2010 can be met given current legislative authorities. Absent other actions, the recent rise in crude oil prices will have little or no impact on the increasing dependence of the U.S. on imported petroleum. The strong growth being experienced by the U.S. economy assures that the trend for increasing energy use will remain strong, and the transportation sector remains 95 percent dependent on petroleum fuels. The real price of petroleum fuels will have to rise more than has recently been experienced, and be sustained for a long period, to cause a change in the trend to increased reliance on imported petroleum. Recent Department of Energy analysis, done on the behalf of the General Accounting Office, however, does indicate that policy initiatives designed to promote the use of alternative fuel, such as fuel tax incentives, in concert with sustained oil prices in excess of $30/barrel, could result in increased alternative fuel market share and, under some circumstances, achieve the EPACT 30 percent replacement fuel goal.

The economic benefits of increased alternative and replacement fuel use, however, remain significant. Even moderate uses of alternative and replacement fuels in place of petroleum can bestow significant economic benefits to the U.S. economy by reducing the global demand and price for oil. Displacing petroleum with alternative and replacement transportation fuels helps hold down petroleum prices in two ways. First, reducing the demand for petroleum decreases the world price for oil. Although the actual impact will depend on precisely how OPEC responds, a

reasonable rule of thumb is that a 1% decrease in U.S. petroleum demand will reduce world oil price by about 0.5%, in the long-run. Short-run (1 year or less) impacts would be even greater, due to the short-run inelasticity of oil supply and demand.

A second benefit of increased alternative and replacement fuel use is its potential to reduce the impact of a supply shortage on prices. As evidenced in the industrial and utility sectors, the existence of alternatives to oil provides potential substitutes for oil in the event of a production cutback. Since it is precisely the non-responsiveness of transportation oil demand to oil production cutbacks that makes oil price shocks possible, increasing competition for oil by using alternative fuels reduces the ability of oil suppliers to constrain supply in order to increase the price of oil.

A recent draft analysis by Oak Ridge National Laboratory estimated oil price reduction benefits of alternative and replacement fuel use.[1] The analysis estimated that even today's modest use of alternative and replacement fuels reduces total U.S. petroleum costs by about $1.3 billion per year (about $0.29 per barrel). Since the passage of EPACT in 1992 to 2000, cumulative savings are estimated to be $9 billion. Increasing non-petroleum fuel use to 10% of motor fuel use by 2010 is estimated to increase oil market benefits to $6 billion per year ($0.68/bbl), for a 2000-2010 cumulative savings of $35 billion. These estimates were made using a very simple model of world oil markets and are contingent on the assumption that historical and projected OPEC production levels do not change.

To help take advantage of the long-term benefits of alternative and replacement fuels, the report provides a sample list of incentives and programs to promote alternative fuel vehicles and the use of alternative fuels; these are still valid.[2] None of the items on the sample list have been negated by the recent rise in crude oil prices; rather the impacts would be enhanced. Price increases and technology improvements are making alternative fuel vehicles and replacement fuels, such as ethanol and natural gas liquids, even more important for our Nation. As the report recommends, now is an excellent time for the Administration and Congress to begin a dialogue on these issues.

June, 2000

---

[1] *Costs of Oil Dependence: A 2000 Update*, May 2000, prepared by David L. Greene, Oak Ridge National Laboratory.

[2] For example, the recent Executive Order 13149 (65 FR 24607, April 26, 2000) which calls for the Federal Fleet to reduce its petroleum consumption by 20% by 2005. This Executive Order revoked Executive Order 13031.

I. CONCLUSIONS

The Energy Policy Act of 1992 (EPACT) has set in motion substantial efforts to increase the use of alternatives to petroleum in the transportation sector. EPACT seeks to achieve this goal via an increase in the use of alternative fuels[3] and alternative fuel vehicles (AFVs), as well as through an expansion of the use of non-petroleum components, or replacement fuels[4], in conventional petroleum-based fuels. EPACT section 502(b)(2) established goals of displacing 10 percent of motor fuel consumption in 2000 and 30 percent of motor fuel consumption in 2010 (10/30 goals), with alternative and replacement fuels.

U.S. Department of Energy (DOE) analyses indicate that the 10/30 goals cannot be met given the limited authorities granted to DOE under EPACT. The current EPACT authorities, even if implemented completely, are insufficient to meet the goals. Meeting the goals would require that a substantial portion of the vehicle population, beyond those mandated by EPACT, use alternative fuels. Additionally, recent trends in petroleum prices have produced the lowest, inflation-adjusted gasoline prices in history, which has diminished the competitive position of alternative fuels relative to gasoline.

DOE analyses, however, suggest that alternative and replacement fuel use in motor vehicles at significant penetration levels (10 to 30 percent) could be sustainable based on underlying economics if the transitional impediments could be overcome. But current market economics alone should not be the sole criterion upon which public-policy decisions are made regarding alternative and replacement fuels. Reduced dependence on imported oil, improved air quality, lower greenhouse gas emissions, and increased domestic economic activity are all potential benefits that can accrue through the use of alternative and replacement fuels.

Despite current market conditions that indicate an abundant supply of petroleum and low inflation-adjusted petroleum product prices, the alternative and replacement fuels goals of EPACT should still be vigorously pursued. The history of inflation-adjusted oil prices has been one of abrupt rises followed by gradual declines. If this pattern persists, another price shock will occur in the future. In the absence of a significant change in current trends, the U.S. is projected to become increasingly dependent on imported petroleum.

---

[3] "Alternative fuels" means methanol, denatured ethanol, and other alcohols; mixtures containing 85 percent or more (but not less than 70 percent, as determined by the Secretary, by rule, to provide for requirements relating to cold start, safety, or vehicle functions) by volume of methanol, denatured ethanol, and other alcohols with gasoline or other fuels; natural gas; liquefied petroleum gas; hydrogen; coal-derived liquid fuels; fuels (other than alcohol) derived from biological materials; electricity (including electricity from solar energy); and any other fuel the Secretary determines, by rule, is substantially not petroleum and would yield substantial energy security benefits and substantial environmental benefits. Section 301(2).

[4] "Replacement fuels" means the portion of any motor fuel that is methanol, ethanol, or other alcohols; natural gas; liquefied petroleum gas; hydrogen; coal-derived liquid fuels; fuels (other than alcohol) derived from biological materials; electricity (including electricity from solar energy); ethers; or any other fuel the Secretary determines, by rule, is substantially not petroleum and would yield substantial energy security benefits and substantial environmental benefits. Section 301(14).

DOE's Energy Information Administration (EIA), in its *Annual Energy Outlook 1999*, projects that the share of U.S. petroleum consumption met by net imports will rise from 49 percent in 1997 to 65 percent in 2020. EIA also forecasts that the Persian Gulf share of total world oil exports is expected to rise to 51 percent at the turn of the century and reach 64 percent by 2020. These projections indicate that the U.S. is likely to become more vulnerable to the economic consequences of petroleum shortages and price spikes. The transportation sector would be particularly impacted since it is 97 percent dependent on petroleum and has not made any significant progress in diversifying its fuel mix.

Alternative and replacement fuels that have lower carbon fuel-cycles than gasoline or diesel fuel also have the added benefit of reducing greenhouse gas (GHG) emissions. The Intergovernmental Panel on Climate Change (IPCC) has stated that the "balance of evidence suggests that there is a discernible human influence on global climate"[5] from the increased concentration of GHGs in the atmosphere. As part of the Kyoto Protocol, GHG emission targets were set for each of the participating developed countries or "Annex I" countries.[6] The U.S. target is a seven percent reduction from 1990 emission levels to be achieved in the 2008 to 2012 time frame. The increased use of lower carbon fuel-cycle alternative and replacement fuels could help the U.S. meet the Kyoto Protocol targets.

Based on the considerable experience gained from vehicle operation mandated by EPACT and related DOE R&D efforts, the following conclusions can be drawn about transportation replacement fuels:

- The technical barriers to the use of alternative and replacement fuels can be overcome (e.g., large numbers of alcohol flexible-fuel vehicles are now in production).

- The vehicles using alternative fuels work well and have operating characteristics that are acceptable to a significant portion of the vehicle-owning population.

- The 10/30 replacement fuel goals, however, cannot be met given the limited Federal authority to promote or require the use of replacement fuels and today's petroleum product prices. DOE, as part of its EPACT rulemaking to determine if private and local fleets should be required to purchase AFVs, will evaluate the goals to determine if they need to be modified given current market conditions.

---

[5] Intergovernmental Panel on Climate Change, *Climate Change 1995: The Science of Climate Change* (Cambridge, UK: Cambridge University Press, 1996).

[6] Annex I countries include Australia, Austria, Belgium, Bulgaria, Canada, Croatia, Czech Republic, Denmark, Estonia, European Community, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Liechtenstein, Lithuania, Luxembourg, Monaco, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, Slovakia, Slovenia, Spain, Sweden, Switzerland, Ukraine, United Kingdom of Great Britain and Northern Ireland, and United States of America.

- Nevertheless, the public-policy goals served by the increased use of alternative and replacement fuels remain strong in terms of reducing U.S. vulnerability to oil price shocks, decreasing emissions of greenhouse gas emissions, lessening criteria pollutants and promoting domestic economic development.

- The policy tools available to DOE to promote replacement fuels, however, are very limited. This situation is exacerbated by the fact that petroleum product prices, adjusted for inflation, have been at historically low levels as recently as the fall of 1999, which hurts the competitive position of alternative fuels.

Despite the fact that alternative fuels have had to compete against low-cost, entrenched petroleum technologies, their introduction via EPACT has produced a number of public-policy benefits. EPACT programs have created an effective "test garden" for the maturation of AFV technologies to the point where earlier operational problems have largely been remedied. EPACT programs have also produced a large pool of flexible fuel vehicles and gaseous-fueled vehicles that provides an energy security buffer in a world where oil prices can still be quite volatile. Additionally, the start of a fledgling alternative fuels infrastructure has established an alternative fuel commitment that could be expanded in an oil supply emergency.

To maintain these societal benefits, Federal efforts should be two-pronged by focusing on both promoting "neat" alternative fuels (such as natural gas, ethanol, electricity, biodiesel, propane and methanol) and also blends of replacement fuels (such as ethanol, ethers and biodiesel) into gasoline and diesel fuel. Petroleum/replacement fuel blends might, in fact, represent a promising pathway by which renewable fuels such as ethanol from biomass might attain sufficient economies of scale to compete with conventional petroleum fuels.

In the rulemaking activities associated with implementing EPACT, some alternative fuel stakeholders expressed a preference for alternative/replacement fuel incentives rather than mandates to purchase AFVs and/or use alternative/replacement fuels. Listed below is a sampling of potential incentives and programs that have been proposed by stakeholders in public comments to DOE, as well as stakeholder forums held by DOE, that could increase the use of AFVs and alternative and replacement fuels:

- **Alternative Fuel Use Tax Credit -** Provides up to a 50 cent/gal tax credit for individuals and firms that use alternative fuels. This approach is similar to legislation introduced in the 106th Congress.

- **Alternative Fuel Vehicle and Infrastructure Tax Deduction/Credit -** Strengthens the current EPACT AFV tax incentives to a larger deduction or a tax credit. The current tax deduction does not provide significant economic incentives to fleets or refueling-facility owners.

- **Alternative Fuel Use Tax Exemption -** Exempts all alternative fuels from the Federal excise tax and makes revenue neutral via a one cent/gallon increase in the gasoline and diesel fuel road tax.

- **Replacement Fuel Tax Incentive -** Provides a tax incentive for any fuel that derives a certain minimum percentage of its energy content from a replacement fuel.

- **Greenhouse Gas Tax Credit -** Provides tax credits for alternative fuels and replacement fuel blends based on their ability to reduce greenhouse gas emissions.

- **Diesel Replacement Fuel Tax Exemption -** Provides a certain tax exemption for the use of renewable replacement fuels, such as biodiesel and ethanol, in diesel fuels similar to those now provided for blending ethanol into gasoline.

- **EPACT Fuel Use Requirement -** Considers extending DOE's authority to require actual alternative fuel use for all mandated EPACT fleets.

This stakeholder sentiment has been reflected in a number of bills (see Table 1) that have been introduced in Congress that would provide incentives for the purchase of AFVs and the use of alternative fuels. Congress should consider a wide range of incentives/programs that could increase the use of alternative and replacement fuels. The Administration and DOE stand ready to work with Congress on identifying which policies would be the most effective in increasing the use of alternative and replacement fuels.

DOE is in the process of evaluating several of these incentives recommended by stakeholders in terms of what impacts they would have on petroleum displacement. In addition, DOE is open to other ideas for petroleum displacement in the transportation sector, such as the increased use of vehicles with significantly higher fuel-efficiency than current vehicles as a means to attain the EPACT replacement fuel goals. DOE, as part of its EPACT rulemaking to determine if private and local fleets should be required to purchase AFVs, will also evaluate the goals to determine if they need to be modified given current market conditions.

It would be prudent for DOE and interested committees of Congress to begin discussions now on possible additional programs and authorities that would contribute to reaching more realistic EPACT goals. The dialog might well involve various alternative concepts and mixes of concepts of energy security, fuel displacement, and conservation. Possible roles for AFVs and infrastructure in establishing capabilities for fuel switching in contingency situations might be considered as partial substitutes for actual ongoing alternative fuel use. DOE will continue to solicit stakeholder views and undertake background analysis pertinent to these issues. In any event, given the obvious need for further clarity and continuity in Federal policy, early engagement in such a dialog by the Executive Branch and the Congress appears to be the proper course to follow.

Table 1
Summary of Bills from the 106th Congress
Relating to Alternative Fuels

Alternative Fuel Vehicles (S.1003, H.R.2252, and H.R.260)

S.1003 is sponsored by Senator Rockefeller and provides a 50 cent per gasoline equivalent gallon tax credit for methanol, propane, hydrogen, and natural gas alternative fuels through 2007. It also provides up to $30,000 per qualified alternative fuel refueling facility. In addition, it provides a $4,000 tax credit for electric vehicles, and $5,000 additional (a total of $9,000) if they have a range of at least 100 miles. It would also exempt alternative fuel vehicles (AFVs) from high-occupancy vehicle restrictions. H.R.2252 is sponsored by Representative Dave Camp and has the same provisions as S.1003. H.R.260 provides the same alternative fuel tax credit as the previous two bills, plus AFV tax credits of $2,000 for light-duty AFVs, $5,000 for medium-duty AFVs, and $50,000 for heavy-duty AFVs, all for businesses within "empowerment zones." It also provides up to $100,000 in tax credits for alternative fuel refueling facilities. H.R.260 is sponsored by Representative Jose Serrano.

Electric Vehicles (S.1230 and H.R.1108)

These bills, sponsored by Senator Barbara Boxer and Representative Mac Collins, have the same provisions: allow 100 percent of the cost of an electric vehicle to qualify for a tax credit of $4,000 and extend the credit through 2008. It would also lift the "government use" restriction on tax incentives to allow companies which lease electric vehicles to government agencies to take advantage of the tax credit, and make electric buses and heavy-duty electric vehicles eligible for the $50,000 tax deduction already in place for all other alternative fuel buses and heavy-duty equipment. Compared to the electric vehicle provisions of the Rockefeller Bill (S.1003), these bills provide less in tax incentives for light-duty electric vehicles (assuming they have 100 miles range or more) and more for heavy-duty electric vehicles. S.1003 would extend the tax credits for electric vehicles to 2008 while S.1230 and H.R.1108 extend the tax credits to 2009.

Use of Inherently Low Emission Vehicles at Airports (H.R.1035, H.R.1000, and S.1174)

H.R.1035 would direct the Department of Transportation (DOT) to provide grants of $2 million per year to up to 10 airports to acquire inherently low emission vehicles (i.e., natural gas, propane, electric, and hydrogen vehicles). H.R.1035 is sponsored by Representative Sherwood Boehlert. The provisions of H.R.1035 are also included in H.R.1000 sponsored by Representative Bud Shuster which reauthorizes programs of the Federal Aviation Administration, and for other purposes. S.1174, sponsored by Senator Harry Reid, is essentially the same as H.R.1000, also including the provisions of H.R.1035.

Potential Legislation

Representative Robert Matsui is preparing to introduce a bill incorporating the Administration's Climate Change Technology Initiative proposal to provide incentives for advanced technology vehicles. This bill is likely to include: (1) extension of the electric vehicle tax credits similar to bills S.1003, H.R.2252, H.R.260, S.1230, and H.R.1108; and (2) incentives for use of advanced technologies that facilitate improvements in light-duty vehicle fuel economy.

II. SUMMARY OF FINDINGS

This report represents a technical and policy analysis required by section 506 of the Energy Policy Act of 1992 (EPACT). It addresses each of the elements that the statute called on the Department of Energy (DOE) to evaluate:

- Progress made in achieving the goals described in EPACT section 502(b)(2), as modified under section 504;

- The actual and potential role of replacement fuels and alternative fueled vehicles in significantly reducing United States reliance on imported oil to the extent of the goals identified in section 502(b)(2); and

- The actual and potential availability of various domestic replacement fuels and dedicated vehicles and dual fueled vehicles.

In addition to addressing the issues posed by the statute for the Technical and Policy Analysis, DOE has chosen to identify and discuss some additional issues and perspectives. These also represent DOE perspectives at this particular moment in time on issues believed to be potentially significant to implementation of EPACT title V programs and possible future directions for alternative fuel policy. In many cases, the answers are yet incomplete, but it is believed that timely public and congressional discourse would be useful in further delineation of issues and approaches.

Energy Security Concerns

The geopolitical context surrounding energy security has changed enormously since the oil shocks of the 1970s for several reasons: the end of the Cold War; a diminution in the market power of the Organization of Petroleum Exporting Countries (OPEC) due to an increase in petroleum production from non-OPEC nations; steady and declining oil prices for most of the last decade; and the cementing of U.S. security ties to the most important oil-exporting nations. Unfortunately, these developments have engendered a complacency on the part of the American public not unlike that which preceded previous oil shocks. The growing dependence of the U.S. on imported petroleum offsets the positive developments that have occurred in the global petroleum market over the past 20 years, i.e., the potential impact of a petroleum shock on the U.S. is growing regardless of its origin or whether it is politically motivated. Historically, periods of low prices have been followed by steep price spikes, a pattern that could well be repeated in coming years.

In contrast to the current geo-strategic environment, economic realities and trends seem to be recreating many of the preconditions for a potential oil shock in the U.S. sometime in the future. Economic growth in the Pacific rim is giving rise to a growth in world oil demand that could well lead to a short-supply situation within the next five to ten years. The world's oil resources are as concentrated as ever in the OPEC nations, notably in the Persian Gulf. DOE's Energy

Information Administration (EIA) projects that by 2010, OPEC's market share is likely to reach the levels of the 1970s, as its share of world supply grows from 41 percent in 1992 to 52 percent in 2000 to over 65 percent in 2020. In addition to concern about concentration of oil resources, new concerns have recently been raised that the peak in oil production could occur within ten years.[7]

The costs to the U.S. economy from a future oil price shock could be enormous. Based on analyses of previous oil shocks, recent studies have estimated the macroeconomic impacts as reducing U.S. economic activity by an average of over 2 percent per year for three to four years or more, which translates into gross national product (GNP) reductions in the range of six hundred billion dollars over three years, up to possibly $3 trillion over fifteen years if the lost economic growth were not subsequently made up.[8,9]

Unlike other energy using sectors, which have introduced substitute fuels and fuel switching flexibility since the oil shocks of the 1970s and 1980s, the transportation sector remains overwhelmingly dependent on petroleum-based fuels (approximately 97.5 percent of transportation energy coming from petroleum) and on technologies that provide virtually no flexibility. The transportation sector currently accounts for approximately two-thirds of all U.S. petroleum use and roughly one-fourth of total U.S. energy consumption. Transportation petroleum consumption has risen from 8.6 million barrels per day in 1992, when EPACT was enacted, to 9.8 million barrels per day in 1998 (14 percent over six years). EIA projects this consumption to rise to 15.1 million barrels per day by 2010 (a 54 percent increase from 1998). U.S. dependence on imported petroleum has also grown since EPACT enactment, from 41 percent in 1992 to 46 percent in 1995 with growth projected to 54 percent in 2000 and 57 percent in 2005. Dependence of U.S. autos and trucks on imported oil was one of the major driving forces behind congressional passage of EPACT, and the imperatives are even stronger now than at the time of passage.

Substitution of petroleum-based transportation fuels (gasoline and diesel) by non-petroleum-based fuels ("replacement fuels," including alternative fuels such as electricity, ethanol, hydrogen, liquefied petroleum gas, methanol, and natural gas) could be a key means of reducing the vulnerability of the U.S. transportation sector to disruptions of petroleum supply. Centrally-fueled fleets are a critical factor in the transportation sector's transition to the use of alternative fuels and vehicles. Early introduction of alternative fuels in these fleets is feasible since fleet vehicles generally refuel at a central facility and/or operate within a fuel tank's driving range of

---

[7] "The End of Cheap Oil," Colin J. Campbell and Jean H. Leberrère, *Scientific American*, Volume 278, No. 3, March 1998.

[8] Energy Modeling Forum, "International Oil Supplies and Demands," EMF Report 11, Vol. II, April 1992, Stanford University.

[9] Greene, David L., and Leiby, Paul N., "The Social Costs to the U.S. of Monopolization of the World Oil Market, 1972-1991," Oak Ridge National Laboratory, March 1993, ORNL-6744.

where they are garaged. Accordingly, fleets feature prominently in title V of EPACT, which aims to displace substantial amounts of petroleum-based motor fuel with alternative fuels.

Progress Toward Achieving the Goals Described in Section 502(b)(2)

Section 502(b)(2) of EPACT suggests tentative goals of displacing 10 percent of transportation fuel with replacement fuels by the year 2000 and displacing 30 percent by the year 2010. DOE is making steady progress in carrying out the provisions of EPACT title V and related programs, which should yield measurable results in alternative fuel and AFV usage in the future. DOE supports and coordinates the Federal Fleet Program for acquisition of alternative fuel vehicles (AFVs), which has resulted in the acquisition of over 44,000 AFVs in the Federal fleet by late 1998. DOE's Clean Cities Program promotes voluntary commitments and coordinated action by the key groups within participating city regions for installation of alternative fuel infrastructure and acquisition of vehicles. As of mid-1998, 72 cities and over 3,500 stakeholder organizations were participating. DOE is also carrying out the rulemaking and analytical activities prescribed by EPACT title V, including implementing AFV purchase requirements for State and alternative fuel provider fleets and determining if such requirements should also be placed on private and municipal fleets. The research, development, and demonstration (RD&D) program has been instrumental in fostering technology development in its two spheres, advanced vehicle propulsion technologies and alternative fuels research and demonstration. The latter is now turning its focus to alternative fuels infrastructure technology. DOE is also involved with the Environmental Protection Agency (EPA) in Clean Air Act programs that promote use of advanced technology vehicles, including alternative fuel vehicles, for use in ozone non-attainment areas.

Actual and Potential Role of Replacement Fuels and AFVs in Reducing Oil Imports

While DOE modeling suggests that the potential use of replacement fuels in the U.S. is very high under certain circumstances, by 1998 the transportation sector had barely scratched the surface of this potential. The preliminary estimate of replacement fuels used in 1998 in the U.S. is about 4.3 billion gallons gasoline equivalent (or 3.6 percent of total highway gasoline use). Of total replacement fuel use, 3.9 billion equivalent gallons, or 90 percent, were oxygenates (3.4 percent of gasoline) and 334 million equivalent gallons, or 10 percent, were alternative fuel used by AFVs (0.3 percent of gasoline). The results of DOE's Technical Report 14,[10] which evaluated the feasibility of reaching the goals suggested by section 502(b), indicate that the potential use of replacement fuels sustainable by the market could be as high as 30 to 40 percent in 2010 under various scenarios.

In order to reach such levels of alternative fuel use, however, major transitional impediments would have to be overcome, including changes in relative fuel/vehicle prices to consumers. For

[10] "Market Potential and Impacts of Alternative Fuel Use in Light-Duty Vehicles: A 2000/2010 Analysis," Technical Report 14 in the Flexible and Alternative Fuel Series, U.S. Department of Energy, Office of Policy and Office of Energy Efficiency and Renewable Energy, January 1996.

example, the EPACT suggested goals of displacing 10 percent of transportation fuels in the year 2000 and 30 percent in the year 2010 would require that AFV sales:

- grow to between 35 and 40 percent of total new light-duty vehicle (LDV) sales by 1999 to meet the 2000 goal; and

- stay in the range of 30 to 38 percent to build an AFV population sufficiently large to meet the 2010 goal.

Even to meet a 30 percent goal for year 2020, AFV growth would have to:

- double every year between now and 2000, going from approximately 30,000 to 500,000 sales per year;

- increase by 50 percent per year to 4,000,000 in the period from 2001 through 2005; and

- remain at a constant 32 percent of total LDV sales in the period of 2005 through 2010.

Under this scenario, the AFV population in 2020 (ten years later than the EPACT 30 percent goal) would be large enough so that 30 percent of LDV motor fuel would be replacement fuel (alternative fuels plus oxygenates used in conventional vehicle fuel). This alternative scenario is believed to be more representative of new vehicle technology market introduction generally than the growth paths necessary to meet the (unmodified) EPACT goals but would still be enormously ambitious.

EPACT programs, if fully implemented, could displace roughly 2 percent of the highway gasoline use projected by EIA for 2010. Replacement fuels in the form of oxygenates and non-EPACT AFVs could contribute an additional 3 to 4 percent of highway gasoline during this period. The gap between these volumes and those necessary to reach or approach the EPACT section 502(b)(2)(B) goal of 30 percent fuel displacement by 2010 would have to be met by AFV use by motorists not covered by these programs, largely by the general public.

Examination of international policy experience shows EPACT fleet programs to be a unique approach. Nonetheless, experience of other country programs does provide the following lessons:

- Spillover into voluntary use of alternative fuels and AFVs in non-mandated sectors is likely to be determined by the relative economic costs and benefits during each stage of the transition, including (at least for dedicated AFVs) some differential to compensate for future uncertainty and for the operational disadvantages of dedicated AFVs.

- Merely putting in place novel and limited infrastructure networks is likely to be insufficient in generating high levels of spillover to non-mandated motorists, even in conjunction with cognizance of societal benefits and potential future widespread availability.

Applying these lessons to the U.S. environment suggests that changes in the overall economics, access, and convenience factors (or the perception of such imminent changes) will be necessary preconditions for AFV penetration in the general public. Such changes could occur in various ways, including policy induced changes, cyclical price swings, or market disruptions.

Experience of other countries also suggests that the political will to support alternative fuel programs is greatest when oil prices are at peak levels. When incentives are most critical to sustaining alternative fuel momentum, at the low end of the oil price cycle, governments have often been least committed.

Actual and Potential Availability of Replacement Fuels and AFVs

Alternative fuel vehicle technologies are available for the principal alternative fuels believed most likely to play major parts in any transition to substantial alternative fuel use. Alcohol, liquefied petroleum gas (LPG), and natural gas vehicle technologies are sufficiently developed for such vehicles to be introduced into the market on large scales. Electric vehicle technology per se is also close to market-ready, but battery cost and range probably limit penetration to select market niches for the next five to ten years. Hybrid electric vehicles are being sold in Japan now with announced plans for them to be sold in the U.S. in the 2000 model year. Fuel cell and hydrogen vehicle technologies are in various stages of development and could play significant roles in the future, probably after 2005.

A number of types of vehicles are currently available for purchase from original equipment manufacturers (OEMs) by the public and fleets, but not the whole range of vehicles for each of the alternative fuels.

- A passenger car, pickup truck, and minivan are available for use with 85 percent ethanol/15 percent gasoline mixtures (E85) or any mixtures down to straight gasoline, at the same price as the conventional fuel model on which they are based.

- Pickup trucks and vans are available in dedicated and bi-fuel compressed natural gas (CNG) configurations. A dedicated CNG full-sized sedan and a subcompact are available, and two bi-fuel compact passenger cars are available. Costs for dedicated CNG vehicles are generally $3000 - $5000 more than conventional models.

- A bi-fuel LPG pickup and a dedicated medium-duty LPG truck are available.

- Two subcompact EV passenger cars, one minivan EV, and three light truck EVs are available.

In addition to these OEM vehicles, dozens of small companies offer systems to convert gasoline vehicles to dedicated or bi-fuel CNG or LPG operation. However, new emission certification

rules for converted vehicles being implemented by the EPA may greatly diminish the number of small conversion companies in the future.

Although alternative fuel refueling sites have been proliferating in recent years, none of the alternative fuels are currently available at retail for vehicle refueling in adequate networks to support widespread use. Adequate refueling sites could be available as a transition proceeds but would involve additional capital costs.

All of the major alternative fuels are available at national and regional levels in volumes sufficient for transportation use at levels significantly greater than the current levels. While this available supply includes both domestic production and imports, domestic supply will be adequate to serve AFV needs for coming years. If alternative fuel use were to approach the levels suggested by the EPACT 30 percent goal, market pressures could change the split between domestic and import supply. Natural gas, ethanol, and electricity have the greatest potential for domestic production to meet large-scale transportation use. LPG and methanol could be available in adequate quantities either domestically or internationally.

Key Issues and Perspectives

While available evidence indicates that substantial spillover from EPACT title V programs into household AFV acquisitions is unlikely in the absence of some economic incentive to households to make the shift, such incentive might occur in any one of a number of ways. It would not necessarily have to represent a Government incentive program.

An oil price rise could well cause dramatic changes in relative prices between gasoline and a number of alternative fuels, resulting in natural fuel switching if the conditions enabling motorists to switch fuels are in place. Comparative historical movements in relative prices for alternative fuels and their feedstocks show clear divergences in price movements from crude oil and gasoline, particularly for electricity, ethanol, and methanol. There is probably no way of reliably assessing the impact of a future oil price rise on the effectiveness of EPACT programs until such an event occurs. On the other hand, it does appear possible to infer from prior experience that a price spike is unlikely to result in major fuel switching in the transportation sector in the absence of certain preconditions relating to the availability of AFVs and alternative fuel infrastructure, which EPACT title V begins to address. It should be noted that most of the fuel switching in Brazil and the Netherlands, the two countries where AFV programs have been most effective, occurred after an oil shock that had been preceded by more modest programs promoting the alternative fuel to which the country partly switched after the shock.

EPACT programs, if they achieve their full potential, could provide incentives to restrain rising oil demand before it leads to a run-up in oil prices of the nature of those discussed above. EPACT programs could also reduce the likelihood or magnitude of a future oil shock in another way. One potential benefit of developing a fuel switching capability is the potential to alter the behavior of primary fuel suppliers. If viable competing fuels are available, the likelihood of a restriction of oil supplies could be diminished. EPACT programs have the potential to shorten

the time lag between an oil price shock and the oil use reductions following it and to magnify such reductions in the key transportation sector, precisely the sector where they have been least substantial up to now. The better the perceived potential of the U.S. to introduce alternatives in the event of an oil price increase, the less the likelihood and/or magnitude of the price increase likely to be sought by oil exporting countries in the event of a supply disruption.[11]

It is also possible that a well designed EPACT initiated process of fuel switching could avoid or reduce the magnitude of problems involved with the relatively abrupt technological transitions in transportation that historically follow major oil shocks and which have also characterized historical fuel switches. Alternative fuel transportation systems could be more fully ripe for widespread deployment and the American public more amenable to fuel switching as results of EPACT fleet programs (as well as DOE RD&D programs). It may never be possible to know with certainty the actual contributions of the EPACT programs in these "insurance policy" roles.

The current international negotiations for greenhouse gas reductions could cause the price of carbon-based fuels in the U.S. to rise substantially, providing incentive for production of low greenhouse gas renewable fuels such as ethanol. U.S. vehicle manufacturers are now producing hundreds of thousand vehicles (at zero incremental cost) that can use ethanol or gasoline as fuel, which could provide further impetus for production of ethanol as a transportation fuel. Given such a scenario, ethanol and other low greenhouse gas renewable fuels could become an integral part of any greenhouse gas reduction strategy by the U.S.

Despite the many uncertainties, it preliminarily appears that the programs authorized by Congress in EPACT will fall substantially short of the year 2010 goal of 30 percent. DOE may need to modify that goal under EPACT section 504, possibly by rolling back the target dates. EPACT provides ample flexibility for DOE to so scale back the ambitious statutory goals rather than to adopt draconian policies. At the same time, DOE understands that many in the Congress, as well as in the affected communities, are very concerned over what is perceived as EPACT's excessive reliance on mandates rather than economic incentives.

Considering the great magnitude of consequences at stake, it would be prudent for DOE and interested committees of Congress to begin discussions now on possible additional programs and authorities that would contribute to reaching, or more meaningfully approaching, EPACT goals. Such dialog and such consideration of additional programs will be beneficial whether the 30 percent replacement fuel goal is to be maintained or is to be modified in some way due to the EPACT programs falling considerably short of that goal, as now appears likely given the current authorities given to DOE. The dialog might well involve various mixes of concepts including energy security, air quality, greenhouse gas reduction, conservation, and fuel displacement policies. Possible roles for alternative fuel vehicles and infrastructures in establishing capabilities for fuel switching in contingency situations might be considered as partial substitutes

[11] While the U.S. share of world oil imports and its importance in the world oil market are likely to be less in the next century than in the 1970s and 1980s, U.S. leadership in alternative transportation fuel policy and technology development could well catalyze similar developments in other importing countries.

for actual ongoing alternative fuel use. DOE will also be soliciting stakeholder views and undertaking background analysis pertinent to these issues as part of the process of establishing its program under section 502 of EPACT. In any event, given the obvious need for further clarity and continuity in Federal policy, early engagement in such a dialog by the Executive Branch and the Congress appears to be a pressing imperative at this critical juncture.

III. INTRODUCTION

Energy Security Concerns

Between October 1973 and January 1974 world oil prices doubled following production cutbacks amounting to 4.2 million barrels per day by certain members of the Organization of Petroleum Exporting Countries (OPEC). Again in 1979-80, a 5.4 million barrel per day production loss from Iran and Iraq, about 9 percent of world production, resulted in a doubling of oil prices. In both instances, OPEC members restrained production in succeeding years, electing to keep prices at the new higher levels. From May to December of 1990 (following the Iraqi invasion of Kuwait), total oil output from Kuwait and Iraq fell by 4.8 million barrels per day, about 7.6 percent of world production. From the second to the fourth quarter of 1990, oil prices again nearly doubled, from $17.50 to $33 per barrel.[12] This latest price shock was short-lived in comparison to the others, as Saudi Arabia put its slack capacity to use, expanding production by 3 million barrels per day to make up most of the lost supply, only to be followed by a similar price shock from January 1999 to May 2000.

The geopolitical context surrounding energy security has obviously changed enormously since the oil shocks of the 1970s. The Gulf war brought home to the Persian Gulf oil producers their own extreme insecurity and dependence on the West and on the U.S. in particular. The prompt increase in output by Saudi Arabia, along with the more efficient functioning of U.S. energy markets, free from the regulatory constraints in place during previous oil crises, preempted actual shortages for U.S. consumers and limited the duration of the speculative run-up in prices to a few weeks, even as the Iraqi occupation of Kuwait continued and the war ensued. Since the Gulf war, the longstanding irritant to U.S. relations with the nations of the Arabian peninsula has been partly eliminated through breakthroughs in the Middle East peace process. The end of the Cold War and the breakup of the Soviet Union have reduced some of the risks associated with access to foreign oil supplies by the U.S. and its allies. Greater diversification of import sources, the existence of the Strategic Petroleum Reserve, more efficient global markets, including future markets, and the removal of inefficient price and allocation controls all suggest that the U.S. may be less vulnerable to the economic damages of supply disruptions than was the case 20 years ago. Unfortunately, these developments, along with oil prices that have been generally low for the last ten years and recently reached historically low levels (inflation-adjusted), may have engendered a complacency on the part of the American public not unlike that which preceded previous oil shocks. Also, the growing dependence of the U.S. on imported petroleum offsets the positive developments that have occurred in the global petroleum market over the past 20 years, i.e., the impact of a petroleum shock on the U.S. is growing regardless of its origin or whether it is politically motivated.

Historically, low prices have been followed by steep price spikes, a pattern that could well be repeated in coming years (see Figure 1). It is true that key oil producing nations have evidenced an awareness that oil price shocks resulting in recessions in the industrialized world or in

[12] Constant 1993 dollars.

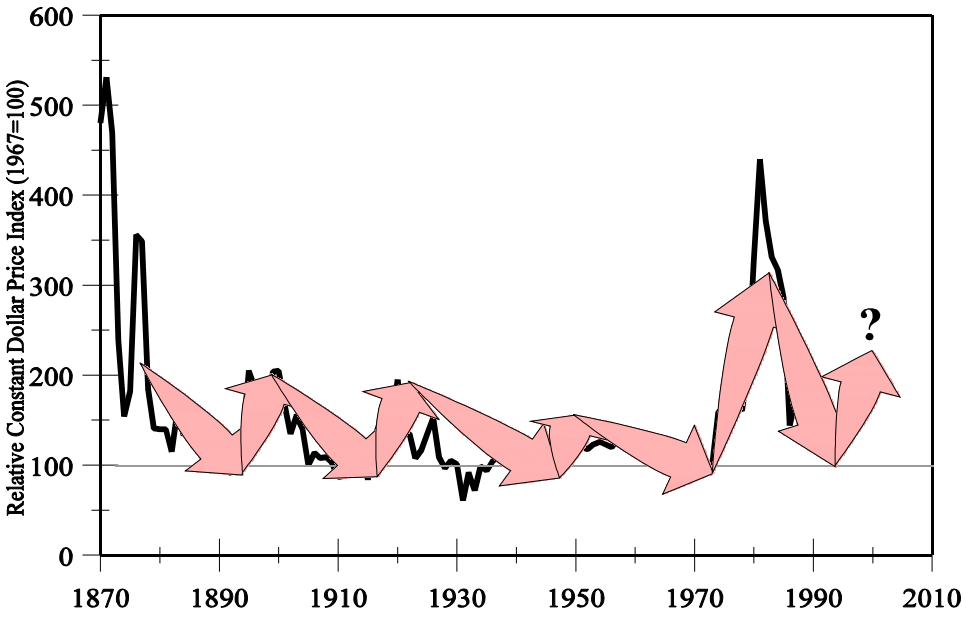


Figure 1. Wellhead Crude Oil Price Movements; Will History Repeat?
Compiled by Danilo J. Santini of Argonne National Laboratory

substitution of energy sources are not in their interest. Some exporters have generally exhibited restraining influence on prices for the last decade. Most, if not all major oil exporting countries have seen their economic and social development devastated by the oil price cycles of the 1970s and 1980s and realize that repetition of the cycle is not in their interest nor that of the consuming nations. This is not to say that the interests of the oil exporters have come to coincide with those of the consuming countries. On the contrary, the pressures for higher prices within many of those countries have probably never been greater. In the event of some supply reducing event, the prices or output levels that they might target could cause substantial economic hardships in the U.S. This is particularly true if the supply disruption affects those key OPEC members with which our strategic relationships are in place.

Existing geopolitical relationships cannot be relied on as the principal sources of energy security for the medium- or long-term. The political stability of even the most critical and most moderate oil producing nations cannot be taken for granted. Neither future regional wars nor revolutions nor coups d'etat can be ruled out in the volatile Middle East region with its many animosities and still inherently unstable internal political structures. Nor, for that matter, can blockage of vital sea lanes such as the Strait of Hormuz be ruled out.

In contrast to the current geo-strategic environment, economic realities and trends could be recreating many of the preconditions for a potential oil shock sometime in the future. Economic growth in the Pacific rim is giving rise to a significant growth in world oil demand that could outstrip the growth of both world and non-OPEC oil capacity, possibly creating a short-supply situation within the next five to ten years. In the 1970s, East Asia consumed less than half as

much oil as did the U.S. Within fifteen to twenty years, East Asian nations will probably be consuming more than the U.S.[13]

In the event of any oil crisis, cooperation among consuming nations could be made more difficult by the greater diffusion of oil demand. Production from the major new oil sources developed during the 1970s and 1980s within the Western World (North Sea and Alaska North Slope) is now beginning to decline. So also are other major non-OPEC sources, at least relative to world markets. The former Soviet Union and Eastern European nations are unlikely to be able to expand exports substantially until at least 2005.

The world's oil resources and particularly its low cost oil resources are as concentrated as ever in the OPEC nations, notably in the Persian Gulf. With the rest of the world drawing down its reserves at nearly twice the rate at which OPEC is using its reserves, OPEC's share of world oil supply is bound to rise, which is exactly what is already happening. DOE's Energy Information Administration (EIA) projects that by 2010, OPEC's market share is likely to reach the levels of the 1970s, as its share of world supply grows from 41 percent in 1992 to 52 percent in 2000 to over 65 percent in 2020.[14] Almost all of the increased OPEC production is expected to be in the Persian Gulf countries.

In addition to concern about concentration of oil resources, new concerns have recently been raised that the peak in oil production could occur within ten years.[15] These concerns are not that the world will run out of oil—rather that after oil production peaks, the price of oil will rise dramatically when it is apparent that consumption is outrunning production. There have been numerous historical predictions of the imminent decline of oil production which have turned out to be premature, and there are many who adhere to the belief that oil discovery and production will keep pace with demand for the foreseeable future.[16] But given the degree to which the planet has been surveyed for oil, it would be imprudent not to take the potential for a peak in oil production and its economic consequences seriously.

The U.S. still consumes more than one-fourth of the world's oil production. About 49 percent of U.S. oil consumption is currently imported compared to about 35 percent at the time of the 1973-74 oil shock. According to EIA, imports are expected to grow steadily from 53 percent of U.S. consumption in 2000 to 60 percent in 2010 and 65 percent in 2020, as domestic oil production continues to decline. Although the Strategic Petroleum Reserve's inventory increased in volume

---

[13] *International Energy Outlook 1998*, April 1998, U.S. Energy Information Administration, DOE/EIA-0484(98), www.eia.doe.gov.

[14] *Annual Energy Outlook 1998*, December 1997, U.S. Energy Information Administration, DOE/EIA-0383(98).

[15] *The End of Cheap Oil*, by Colin J. Campbell and Jean H. Leberrère, Scientific American, Volume 278, No. 3, March 1998.

[16] *Are We Running Out of Oil?*, by Edward D. Porter, American Petroleum Institute, Policy Analysis and Strategic Planning Department, Discussion Paper #081, December 1995.

from 1988 to 1994, it decreased relative to the growth in U.S. net imports so that it now provides the equivalent of only 63 days import supply compared to 96 days supply in 1988.[17]

The costs to the U.S. economy from a future oil price shock could be enormous. Based on analyses of previous oil shocks, recent studies have estimated the macroeconomic impacts as reducing U.S. economic activity by an average of over 2 percent per year for four years or more. This translates to reductions to U.S. GNP in the hundreds of billions of dollars. If the economy were not to subsequently make up for the lost output but only to resume its natural rate of growth, the costs could amount to some $3 trillion over fifteen years, using a discount rate of 10 percent.[18,19]

The General Accounting Office (GAO) made their own estimate of the economic costs of oil disruptions and concluded that each could be on the order of tens of billions of dollars per year.[20] However, they also concluded that replacing inexpensive imported petroleum with more costly domestic production of oil would cost the U.S. much more annually. But they also conceded that oil supply disruptions impose military and other costs that are not easily quantified. They agreed that it was in the interest of the country to develop cost-competitive alternatives to petroleum in the long run, particularly in the transportation sector.

Moreover, U.S. national security is directly related to the security of its energy supplies. Changes in U.S. military doctrine and force structure amplify this relationship. For example, the 582,000 U.S. forces during the Operation Desert Storm consumed more than 450,000 barrels of light petroleum products per day, more than four times the daily use by the entire two million person Allied Expeditionary Force in World War II Europe. The ability to redeploy forces around the globe rapidly, requiring highly intensive energy use, is one of the fundamental pillars of the new strategic framework.[21]

---

[17] *25th Anniversary of the 1973 Oil Embargo—Energy Trends Since the First Major U.S. Energy Crisis*, September 17, 1998, U.S. Energy Information Administration, www.eia.doe.gov.

[18] Energy Modeling Forum, "International Oil Supplies and Demands," EMF Report 11, vol. II, April 1992, Stanford University.

[19] Greene, David L., and Leiby, Paul N., "The Social Costs to the U.S. of Monopolization of the World Oil Market, 1972-1991," Oak Ridge National Laboratory, March 1993, ORNL-6744.

[20] *Energy Security - Evaluating U.S. Vulnerability to Oil Supply Disruptions and Options for Mitigating Their Effects*, U.S. General Accounting Office, Report to the Chairman, Committee on the Budget, House of Representatives, Report GAO/RCED-97-6, December 1996.

[21] *Natural Gas Vehicles: Helping Ensure America's Energy* Security, The National Defense Council Foundation, 1995, p. 4, citing *Oil and War*, Robert Goralski, William Morrow & Co., 1987; *Moving Mountains: Lessons in Leadership and Logistics from the Gulf War*, Lt. Gen. William G. Pagonis, Harvard Business School Press, 1991.

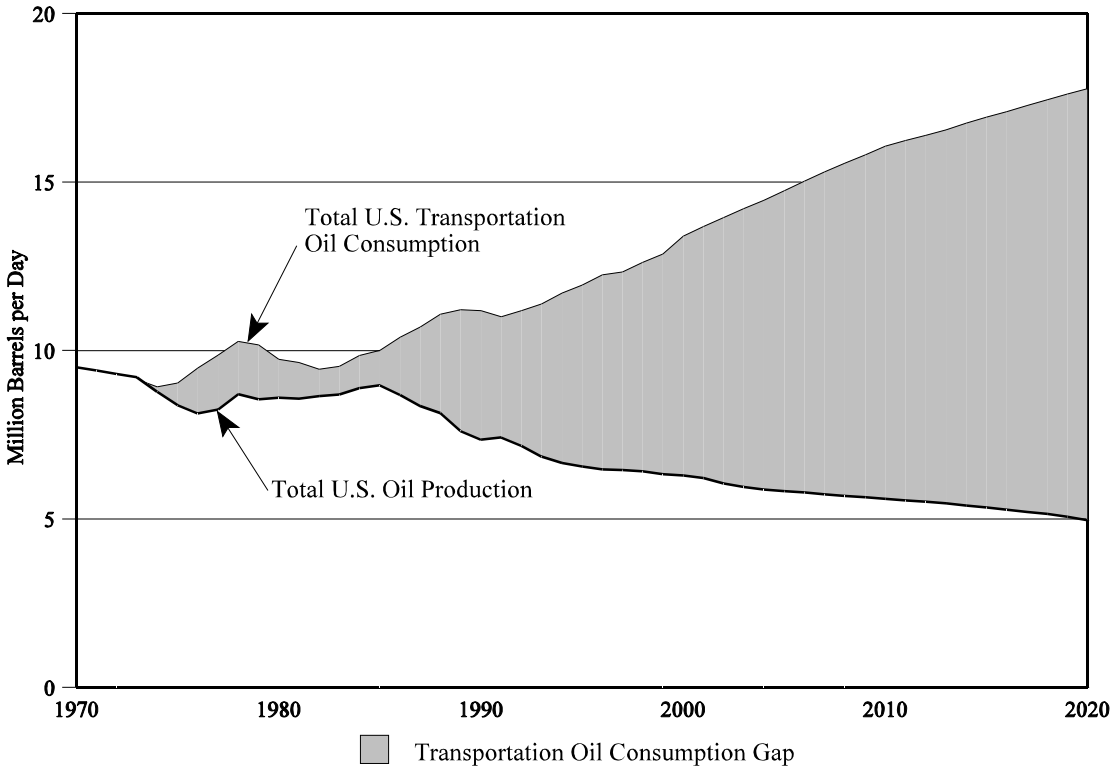


Figure 2. U.S. Transportation Oil Gap

Importance of the Transportation Sector

Since the oil supply/price shocks of the 1970s, U.S. energy use has changed dramatically as our economy, technology, and consumption patterns have responded in a wide variety of ways, including reductions in consumption, increases in efficiency, and diversification of energy types. The single major exception to this positive market response has been the transportation sector. The beneficial effect of federally mandated fuel economy standards for automobiles has been largely offset by motorists driving more miles every year. And, unlike other sectors where mixes of fuels have emerged — in many cases with user capability to switch on moderately short notice — the transportation sector remains overwhelmingly dependant on petroleum-based fuels (approximately 97.5 percent of transportation energy coming from petroleum) and on technologies that provide virtually no flexibility.

The transportation sector currently accounts for approximately two-thirds of all U.S. petroleum use and roughly one-fourth of total U.S. energy consumption. The gap between the transportation sector's demand for petroleum and U.S. petroleum production continues to widen (see Figure 2). U.S. consumption of petroleum in the transportation sector alone exceeds by 5.9 million barrels total U.S. domestic petroleum production; that gap is projected to rise to 12.8 million barrels per day by the year 2020. According to EIA projections, the transportation sector

will consume 17.8 million barrels per day of petroleum in 2020. About ten million of these barrels are projected to be used by light-duty vehicles. Energy for the transportation sector truly represents one of the major sources of short-and medium-term vulnerability for American society and the American economy today. Substitution of petroleum-based transportation fuels (gasoline and diesel) by non-petroleum-based fuels ("replacement fuels," including alternative fuels such as electricity, ethanol, hydrogen, liquefied petroleum gas, methanol, and natural gas) could be a key means of reducing the vulnerability of the U.S. transportation sector to disruptions of petroleum supply.

EPACT Title V

Centrally-fueled fleets are critical to the transportation sector's transition to alternative fuels and vehicles. These fleets are much more amenable to introduction of alternative fuels since they generally refuel at a central facility and operate within a fuel tank's driving range of that central facility. If the necessary infrastructure for alternative fuels is installed at the central facility, the alternative fueling capability could be made available to other parties, including both other fleet operators and the general public. In many cases, the central fueling facility may, in fact, be a commercial station that would be available to the public. Fleet AFV usage could also provide the necessary volume for manufacturers to justify introduction of new AFV models, more options on AFVs and more ready availability in terms of lead time and delivery. Fleet vehicles are generally resold after a few years so that some fleet AFVs could find their way into the general vehicle population. Fleet vehicles typically are driven more than private vehicles, using more fuel and providing more scope for fuel replacement by alternative fuels.

In recognition of the vulnerability of the U.S. transportation system to disruptions of foreign oil supplies and the opportunities for alternative fuel use by centrally fueled fleets, Congress enacted the Energy Policy Act of 1992 (EPACT), including as part of EPACT's core, title V on the displacement of conventional motor fuel by non-petroleum energy sources, focusing on light-duty motor vehicle fleet operations. While title V mandates certain fleets to begin acquiring vehicles capable of operating on alternative fuels, these mandates are not intended, in and of themselves, to provide major reductions in U.S. petroleum use or dependence. Rather, these key vehicle operations are intended to pave the way for alternative fuel use and fuel flexibility for society at large by demonstrating the in-use practicability of the technology on a substantial scale and to provide the necessary critical mass to catalyze markets into supplying alternative fuels and vehicles with sufficient scale and access. In this way, the title V programs would plant the seeds for growth of alternative fuel vehicle use.

IV. PROGRESS MADE IN ACHIEVING THE GOALS DESCRIBED IN SECTION 502(b)

Section 506(b)(1) of EPACT requires DOE to evaluate in this Technical and Policy Analysis the "progress made in achieving the goals described in section 502(b)(2), as modified under section 504." Section 502(b)(2) of EPACT suggests goals of displacing 10 percent of light-duty transportation fuel with replacement fuels by the year 2000 and displacing 30 percent by the year 2010, with at least half of such fuels being from domestic sources.[22] DOE is making steady progress in carrying out the provisions of EPACT title V and related programs, which should yield measurable results in replacement fuel and AFV usage in the future. Many of the programs authorized by EPACT have not been in place long enough to allow a credible assessment of program impacts. The statutory requirement for this Technical and Policy Analysis actually precedes the start of implementation for some of the EPACT programs.

DOE supports and coordinates the Federal Fleet Program for AFV acquisition, which has resulted in the acquisition of 44,000 AFVs by late 1998. DOE's Clean Cities Program promotes voluntary commitments and coordinated action by the key groups within participating city regions for installation of alternative fuel infrastructure and acquisition of vehicles. As of mid-1999, 72 cities and over 3,500 stakeholder organizations were participating. DOE is also carrying out the rulemaking and analytical activities prescribed by EPACT title V, including its study of the technical and economic feasibility of reaching the 10 percent and 30 percent goals and ongoing reports of the demand estimates and supply information required by section 503. DOE's alternative fuels research, development, and demonstration programmatic activities have also been instrumental in fostering technology development in two spheres, advanced vehicle propulsion technologies and alternative fuels research and demonstration. DOE is also involved with EPA in Clean Air Act programs that promote use of advanced technology vehicles, including alternative fuel vehicles, for use in certain air quality non-attainment areas.

The paragraphs that follow summarize the status of the key activities and programs that contribute toward the goals suggested in section 502 of EPACT.

Federal Fleet Program

The Federal Government is working aggressively to acquire alternative fuel vehicles for its own vehicle fleets, as intended by EPACT and the Alternative Motor Fuels Act of 1988 (AMFA). EPACT section 303 requires the introduction of light-duty AFVs into Federal fleets in specific incremental percentages over the next several years. President Clinton, on April 21, 1993, issued Executive Order 12844 (58 FR 21885), which increases the acquisition requirements by 50 percent for 1993-95 over the levels required by section 303. This Executive Order was later

[22] These suggested numerical goals that DOE is to evaluate are apparently suggestions for what might represent the basic objective described in section 502(a) to "... promote the use in light duty motor vehicles of domestic replacement fuels. Such program shall promote the replacement of petroleum motor fuels with replacement fuels to the maximum extent practicable."

superseded by Executive Order 13031. President Bush had earlier issued Executive Order 12759 (April 1991) requiring Federal agencies to annually purchase the maximum practicable number of alternative fuel vehicles. Executive Order 13123, 64 FR 30851 (June 8, 1999) revoked Executive Order 12759. The Department of Energy has the primary responsibility for coordinating Federal efforts on alternative fuels, including implementation of AMFA, EPACT section 303, and Executive Orders pertaining to alternative fuels and alternative fuel vehicles.

President Clinton issued Executive Order 13031 on December 13, 1996, that reinforced the Federal Government commitment to acquire AFVs and use alternative fuels in those vehicles. In addition, this executive order requires agencies to issue annual compliance reports; it allows credits for medium- and heavy-duty AFVs (two AFV credits for each medium-duty vehicle and three AFV credits for each heavy-duty vehicle) in place of light-duty AFVs; it provides up to $10,000 towards the incremental cost of electric vehicles that are acquired by Federal agencies; it requires that agencies must fund the incremental costs of AFVs from their own budgets; and it also directs DOE to work with agencies procuring AFVs to coordinate vehicle placement with non-Federal alternative fuel stakeholders. Executive Order 13031 supersedes Executive Order 12844.

As of the end of 1998, over 20,000 alternative fuel vehicles were either on the road or on order for Federal agencies, including the U.S. Postal Service, the Defense Department, and the General Services Administration (GSA), among other agencies. This program has dramatically increased the use of AFVs, has prompted automakers to expand AFV availability, and is encouraging the alternative fuel industry to plan and invest in a growing refueling infrastructure.

Vehicle Acquisition Process

The Department of Energy works closely with each agency to identify needs for alternative fuel vehicles. Information acquired includes vehicle types and fuel types needed to meet agency mission requirements. Working with the GSA, a solicitation for vehicles is prepared, normally in the late summer. Bids are received in September; evaluation and award usually take place by October or November. Subsequent to award, agencies can order vehicles from the GSA award list. Agencies can also purchase alternative fuel vehicles directly from the manufacturer. Some agencies, including the Postal Service and the Defense Department, typically do not purchase through GSA. Through 1996, each agency provided full funding for its vehicle purchases, and the DOE reimbursed the agency—through an Interagency Agreement established for this purpose—for the incremental cost of the AFV relative to a conventional vehicle. After 1996, each agency became responsible for the full costs of AFVs, except for electric vehicles for which one-half of the incremental cost (up to $10,000) is to be reimbursed by DOE.

Section 8 of the Energy Conservation Reauthorization Act of 1998 (ECRA) (Public Law 105-388), which was enacted on November 16, 1998, also amended section 310 of EPACT to require all Federal agencies subject to EPACT AFV purchase requirements to prepare and submit to Congress an annual report summarizing if the agency is in compliance with EPACT AFV purchase requirements, and, if not in compliance, how it intends to achieve compliance.

Compliance plans in the annual reports to Congress are to contain specific dates on when an agency intends to achieve compliance.

Funding History

The Department of Energy received appropriations of $7 million in fiscal year 1993, $18 million in fiscal year 1994, and $10 million in fiscal year 1995 (after an additional $10 million was rescinded) for the Federal AFV programs. These funds were used to reimburse Federal agencies for the incremental costs of alternative fuel vehicle acquisition. The Department of Energy has not received any appropriations since fiscal year 1995 for Federal AFV programs.

Additional funding contributed by GSA, the Defense Department (DOD), and the U.S. Postal Service (USPS) has supplemented the DOE AFV funding. DOD received appropriations to perform research and development and to acquire natural gas vehicles in the amounts of $10 million for fiscal year 1993, $15 million for fiscal year 1994, and $10 million in fiscal year 1995. DOD has also received electric vehicle funding of $15 million in fiscal year 1995, $15 million in fiscal year 1996, $15 million in fiscal year 1997, and $14.5 million in fiscal year 1998. The U.S. Postal Service has also acquired a significant number of AFVs with its own (non-appropriated) resources. GSA provides funding from its revolving fund that is available from vehicle recalls and canceled orders. DOE provides critical support to industry initiatives to provide vehicles to GSA and the USPS. A summary of Federal AFVs in use is shown in Table 1.

Table 1. Federal Alternative Fuel Vehicles in Use

Year	CNG	M85	E85	LPG	Electric	LNG	Total
1991	104	70	0	103	0	0	277
1992	303	2,590	25	110	35	0	3,063
1993	2,576	5,564	114	123	113	0	8,490
1994	7,022	9,291	139	35	102	35	16,624
1995	9,432	9,552	389	141	191	47	19,752
1996	13,945	7,668	1,748	195	197	78	23,831
1997	13,411	4,177	2,888	183	279	93	21,031
1998	13,856	1,477	4,136	347	349	187	20,352
1999	13,856	1,477	10,086	697	699	252	27,067

Source: Energy Information Administration

Clean Cities Program

The Clean Cities Program was initiated by DOE to serve the goals established by EPACT and specifically serves as DOE's mechanism for seeking voluntary commitments from suppliers, providers, and fleet purchasers as required by section 505 of EPACT. Clean Cities is designed to

expand the use of alternative fuel vehicles in communities throughout the country and to provide refueling and maintenance facilities for their operation. Through the establishment of locally-based Government and industry partnerships, and supported by Federal guidance and leadership in vehicle acquisitions, Clean Cities seeks to build the foundations for a sustainable, nationwide alternative fuels market.

Goals

The primary goal of the Clean Cities Program is to combine Government objectives for energy security, fuel diversity, air quality, and economic opportunity with commercial objectives and voluntary commitments from fuel suppliers, vehicle suppliers, and fleet owners to form the critical, locally-based partnerships necessary to:

(1) Communicate that valid economic choices exist among transportation fuels and identify the benefits of using AFVs;

(2) Promote the use of domestically produced, clean-burning alternative fuels;

(3) Create commercial opportunities and contribute to economic development, including developing alternative fuel supply infrastructure, vehicle manufacture and conversion, service and maintenance, and domestic fuel production and distribution; and

(4) Improve air quality and support the objectives of the Clean Air Act (CAA), including its 1990 Amendments.

Approach

Clean Cities establishes a systematic process of working with communities to develop local plans for creating an alternative fuels market. The program builds on local initiative, identifies options to local problems, and creates partnerships as the mechanism to develop solutions. Clean Cities works directly with local businesses and governments to shepherd them through the goal-setting, coalition-building, and commitments process necessary to establish the foundations for a viable alternative fuels market. Then, by sharing local innovation along the Clean Cities network "mayor-to-mayor," by relating local issues to State and Federal objectives, and by providing continuous customer feedback to the more than a thousand industry and public stakeholders, DOE can help each Clean City to build an enduring program. Ultimately, the Clean Cities approach demonstrates that the alternative fuels challenge has many solutions—which ease the transition for those communities required to implement EPACT and CAA, minimizing the use of additional regulation while achieving comparable results through market processes.

Accomplishments

By mid-1999, the Clean Cities Program had created partnerships in 72 cities throughout the country. The overwhelming national interest carried the program beyond Secretary O'Leary's

1994 goal of 25 cities. Participating fleet operators within these "pioneer" Clean City Programs are operating or planning to be operating over 200,000 AFVs within the next two years—helping to reduce dependence on foreign oil and improve air quality. The programs comprise over 3,500 stakeholder organizations nationwide, committed to significant increases in alternative fuel vehicle acquisitions and infrastructure investment over the next five years. Currently, the program covers over half of the ozone non-attainment areas, including nineteen cities in the Ozone Transport Region (Northeastern States sharing a regional ozone problem), and continues to gain momentum.

To date, DOE has awarded $9.6 million in grants to 117 co-funded pilot projects submitted by State governments to accelerate the introduction of alternative fuels and vehicles. The grants are closely linked to Clean Cities and will play an important role in developing contributions from States and cities that have previously stepped forward to make alternative fuel commitments to the program. Moreover, by awarding incentive funds to support these projects, DOE is able to provide additional support to local initiatives, and leverage the limited public resources for the expansion of the alternative fuels market.

EPACT Rulemaking Activities

Alternative Fuel Provider and State Fleet AFV Acquisition Requirements

Regulations governing the Alternative Fuel Provider Mandate (section 501) and the Mandatory State Fleet Programs (section 507(o)) were published in the *Federal Register* on March 14, 1996 (61 *Fed. Reg. 10622*). These programs require that 90 percent of new vehicles acquired by certain alternative fuel providers be alternatively fueled by 2000 and 75 percent of vehicles acquired by State government fleets be alternatively fueled by 2001. The notice also established rules to govern a credit trading program (authorized by section 508) for required AFV acquisitions by covered entities under these mandates.

State Grants

DOE published a Notice of Proposed Rulemaking for the State and Local Incentives Program under EPACT section 409, March 21, 1995 (60 *Fed. Reg.* 15020). Although no funds have been appropriated for this program specifically, such funding for State AFV programs has been included in the consolidated State Energy Program grants. This consolidated grant program will make funds available to certain States that adopt aggressive and/or innovative policies for AFV deployment and alternative fuel utilization. To date, $9.6 million has been used to fund 117 projects with matching funds coming from States, local governments and the private sector. In many cases, the matching funds exceed the grant amount by several multiples.

Private and Local Government Fleet AFV Acquisition Requirements (Early Schedule)

DOE published an Advance Notice of Proposed Rulemaking as required by EPACT section 507(a)(3) for a possible rulemaking under section 507(b) on August 7, 1996 (61 *Fed. Reg.*

41032). Section 507(b) requires DOE to undertake a rulemaking process to determine whether an AFV mandate for private and local government fleets is necessary to meet the EPACT section 502(b)(2)(B) goal of 30 percent motor fuel displacement by 2010, whether that goal is practicable and achievable, and whether various requisite conditions (relating to vehicle and fuel availability) are met. Section 507(a)(3) requires that this process be initiated with an Advance Notice of Proposed Rulemaking for the purposes of:

- Evaluating the progress toward achieving the goals of replacement fuel use described in section 502(b)(2), as modified under section 504;
- Identifying the problems associated with achieving those goals;
- Assessing the adequacy and practicability of those goals; and
- Considering all actions needed to achieve those goals.

DOE's Advance Notice requested comments on these issues as well as on issues germane to the rulemaking for the possible future mandate. Three public hearings were held on the Advance Notice in September and October of 1996 and the public comment period closed on November 5, 1996. A total of 70 persons spoke at the three hearings and 105 written comments were received by the November 5, 1996, deadline.

On April 23, 1997, DOE published a Notice of Termination stating that DOE would not promulgate regulations to implement alternative fueled vehicle requirements for certain private and local government fleets according to the early schedule of section 507(a)(1) of the Act (62 *Fed. Reg.*19701).

Private and Local Government Fleet AFV Acquisition Requirements (Late Schedule)

Under EPACT section 507(e), DOE has the authority, should it not institute the private and local government AFV purchase mandate under the section 507(a) early schedule, to require certain private and local government fleets to purchase certain percentages of AFVs under the late schedule established by EPACT section 507(g). DOE is presently in the midst of determining whether the private and local government AFV fleet program as stipulated in EPACT section 507(g) should be implemented.

On April 17, 1998, DOE issued an Advance Notice of Proposed Rulemaking on AFV Acquisition Requirements for Private and Local Government Fleets (*63 Fed. Reg. 19372).* The notice requested comments on, among other things, whether the establishment of such an acquisition program under the late schedule in EPACT section 507(g) is necessary for achieving EPACT's replacement fuel goals and whether this program will enable the actual realization of these goals. DOE also held three regional public hearings in May and June 1998 to receive public comment on the issue. A total of 35 persons spoke at the three regional hearings and 83 written comments were received.

P-Series Fuel Alternative Fuel Designation

In response to a petition filed by Pure Energy Corporation, DOE proposed on July 28, 1998, to amend the rules for the statutory program requiring certain alternative fuel providers and State government fleets to acquire an increasing percentage of AFVs from among their purchases of new light-duty vehicles (*63 Fed. Reg. 40202*). The regulatory amendments proposed would add certain blends of methyltetrahydrofuran, ethanol and hydrocarbons known as the P-series fuels to the EPACT definition of "alternative fuel." DOE issued a final rule on May 17, 1999, designating the P-series fuels as alternative fuels (*64 Fed. Reg. 26822*).

Biodiesel Fuel Use Credit

The Energy Conservation Reauthorization Act of 1998 (ECRA) (Pub. L. 105-388) amended EPACT to create the biodiesel fuel use credit. The biodiesel fuel use credit is a mechanism for the allocation of an alternative fuel vehicle (AFV) acquisition credit for a specified amount of biodiesel fuel use by a fleet or covered person currently required to purchase a certain percentage of AFVs under EPACT's titles III and V AFV purchase requirements.

Although EPACT did not designate biodiesel blends as an "alternative fuel," it does allow DOE to allocate one AFV credit to a fleet or covered person for each "qualifying volume" of the biodiesel component of a fuel containing at least 20 percent biodiesel by volume that is purchased for use in vehicles owned or operated by the fleet or covered person that weigh more than 8,500 pounds gross vehicle weight rating. The "qualifying volume" is set equal to 450 gallons of "neat" biodiesel. So, for example, if a fleet wished to qualify for the credit using neat biodiesel (100 percent biodiesel by volume), it would need to purchase 450 gallons of neat biodiesel for use in vehicles in excess of 8,500 lbs. Alternatively, if a fleet wanted to qualify for the credit using B-20 (a biodiesel blend of 20 percent biodiesel/80 percent petroleum diesel by volume), it would need to purchase 2,250 gallons of B-20 for use in vehicles weighing in excess of 8,500 lbs.

DOE on May 19, 1999, issued an Interim Final Rule (*64 Fed. Reg. 27169*) to allow for the use of the biodiesel fuel use credit by fleets and covered persons as a means of complying in part with EPACT's AFV purchase requirements.

EPACT Analytical and Informational Activities

Replacement Fuel Goals

Title V of EPACT suggests ambitious goals for the replacement of petroleum-based motor fuels. DOE is in the process of assessing the technical and economic feasibility of displacing 10 percent of motor fuel by 2000 and 30 percent by 2010. Despite aggressive steps to increase alternative fuel use by State and local governments, industry, Clean Cities, and fleets, it is unlikely that these efforts will be adequate to attain the EPACT goals. As part of the process of assessing feasibility, DOE is investigating additional programs that would contribute toward the goals. For

example, DOE is analyzing potential contributions of alternative fuel incentive programs in meeting the motor fuel displacement goals. The Department has encouraged an ongoing public dialog on these issues and will continue to do so in its EPACT rulemaking activities.

Replacement Fuel Demand and Supply Program

EPACT section 502(a) requires DOE to establish a program to promote the development and use of domestic replacement fuels in light-duty motor vehicles. The program is to promote the replacement of petroleum motor fuels with replacement fuels to the maximum extent practicable and to ensure availability of those replacement fuels that will have the greatest impact in reducing oil imports, improving the health of the U.S. economy, and reducing greenhouse gas emissions. Development of this program will necessarily be based on the foundations from the other analytical activities, including the section 502(b) activities (discussed below) and, particularly, the public dialog DOE expects to be initiated with the section 506 reports.

Under section 502(b), DOE is to determine the technological and economic feasibility of replacing 10 percent of traditional fuels by 2000 and 30 percent by 2010, with at least half of the replacement fuels coming from domestic sources. In addition, DOE is to determine the best means and methods for increasing U.S. production of alternative fuels and to estimate domestic and foreign production capacities for the replacement fuels and AFVs needed to meet the current fuel replacement goals, as well as the effects that the replacement fuels will have on greenhouse gas emissions. The methodology for this study was published in the *Federal Register* on October 4, 1993, (58 *Fed. Reg.* 51622) and partial results were published in January 1996 as *Technical Report Fourteen* in the DOE Office of Policy's series *Costs and Benefits of Flexible and Alternative Fuel Use in the U.S. Transportation Sector*. The study found that displacing 30 percent of light-duty vehicle motor fuel use with alternative fuels was feasible. However, the feasibility was based on a number of assumptions that may not be realized without additional alternative fuel initiatives. The study stated that with a fully established refueling infrastructure, sufficient vehicle availability, and fuel price projections that prevailed in 1996, market forces could continue to support 30 percent use of alternative fuels.

The conclusions of *Technical Report Fourteen*, however, were based on the assumption that alternative fuel infrastructure was widely available and economies of scale in AFV production had been achieved. DOE, and a number of stakeholders, recognized that the costs and impediments of providing a well-developed alternative fuels infrastructure and achieving high-volume AFV production market could be substantial. To address this issue, DOE has begun an ongoing analysis of the feasibility of reaching the EPACT goals through the identification of possible transition pathways. This is being pursued through the use of the Transitional Alternative Fuel Vehicle model (TAFV). The TAFV modeling effort is focusing on the no-transitional barrier cases as in *Technical Report Fourteen*, as well as the market penetration of alternative fuels under various alternative fuels initiatives. Draft TAFV results derived in 1998 have reaffirmed the view that the transitional barriers are significant and strong incentives/programs of sufficient duration will be needed to increase the use of alternative fuel in a significant way. DOE expects to incorporate the TAFV results into its determination of

whether certain private and local government fleets should be required to purchase AFVs as stipulated in EPACT section 507(g).

Replacement Fuel Demand Estimates and Supply Information

EPACT section 503 requires DOE to estimate, on an annual basis, the number and geographic distribution of each type of AFV in use in the U.S., the amount and distribution of each type of alternative fuel, and the greenhouse gas emissions produced from the use of each alternative fuel.

This activity is being conducted by the DOE Energy Information Administration. Fuel suppliers and AFV manufacturers must provide EIA with information concerning fuel supplies and AFV production. EIA has released numerous reports to date complying with the section 503 requirements. The first, entitled *Alternatives to Traditional Transportation Fuels: An Overview* (DOE/EIA/-0585/0), was issued in June 1994. Since 1993, EIA has produced an annual report titled *Alternatives to Traditional Transportation Fuels* that summarizes the total number of AFVs operating in the U.S. and estimates the amount of alternative fuel used by them. Key data from these documents are used in Section V of this report. The most recent EIA data were released on October 22, 1998 and are available through the EIA website (http://www.eia.doe.gov).

DOE Research, Development, and Demonstration Programs

EPACT-mandated research and development is being conducted within the framework of the DOE Office of Transportation Technologies research and development program. This program is split into two major research and development focus areas: 1) advanced vehicle propulsion technologies that will enable substantial increases in vehicle fuel economy, and 2) cost-competitive domestic alternative fuels. Both of these areas will help to achieve energy security and transportation fuel diversity, reduced emissions from mobile sources, and more competitive U.S. vehicle and fuel industries.

Advanced Vehicle Propulsion Technologies

Through strategic partnerships such as the United States Advanced Battery Consortium and the Partnership for a New Generation of Vehicles (PNGV), the advanced vehicle propulsion system development program is pursuing many parallel research efforts in:

- Hybrid propulsion systems;
- Transportation fuel cell development;
- Improved energy storage technology;
- Advanced materials technology; and

- Advanced heat engine technologies.

Alternative Fuels Research, Development, and Demonstration

The alternative fuels program is conducting several research and development projects to:

- Stimulate development of technologies to lower the cost and improve the performance of vehicles that use alternative fuels, particularly natural gas, alcohols, and electricity;

- Assist the introduction of alternative vehicles/fuels that can be competitive with conventional fuels and vehicles; and

- Stimulate development of technologies that provide abundant, cost-effective fuels from domestic resources.

Not all of DOE's work is conducted in the test labs. As a continuation of earlier Alternative Motor Fuels Act of 1988-originated activities, on-road fleet testing is currently being conducted on a cross section of light-duty vehicles, trucks, and buses. These fleet tests encompass several major geographical regions that represent diverse climate and use conditions.

DOE has been instrumental in fostering AFV technology in the U.S. In the 1970s and 1980s, the focus of DOE support was on basic engine and vehicle development. As successes in this area were achieved, demonstrations of the vehicle technology were conducted to quantify their performance. During this time, it became apparent that AFVs had additional potential to reduce the emissions from vehicles that degrade air quality and/or contribute to global warming. In the late 1980s and early 1990s, as the vehicle manufacturers brought AFVs to market, the focus of DOE alternative fuel efforts broadened to include public outreach programs. For instance, working with the private sector, DOE has established a National Certification Program for alternative fuel vehicle training programs for automotive technicians. This should assure that properly trained automotive technicians will be available to service alternative fuel vehicles using proper and safe procedures. DOE has also initiated several public education actions including development of several brochures and the National Alternative Fuels Hotline, where anyone can phone in and ask questions about alternative fuel vehicles. The implementation of these programs illustrates the realization by DOE that alternative fuel vehicles were becoming sufficiently technically mature for commercialization.

Implementation of the Alternative Motor Fuels Act was a turning point away from research to infrastructure development; this paved the way for implementation of EPACT AFV programs. However, it should be noted that research and development is still being supported by DOE in those alternative fuel vehicle technology areas such as electric, fuel cell, hybrid and hydrogen vehicles that have not reached the same level of maturity as methanol, ethanol, natural gas, and LP gas vehicles have to date. Without this continued research and development, AFV technology will not be ready for a program as large and far-reaching as EPACT.

Coordination with EPA Program

Section 246 of the Clean Air Act, as part of the Clean Air Act Amendments of 1990 (Pub. L. 101-549), requires certain fleet operators located in extreme, severe, and serious ozone non-attainment areas to acquire "clean fuel fleet vehicles" for their fleets, beginning in model year 1999. The Environmental Protection Agency has published a series of rules governing this program. Many of the same fleet operators covered by the EPA program will also be covered by EPACT fleet acquisition requirements. Indeed, many of the vehicles within the fleets could be used to meet the requirements of both programs. DOE believes that the two programs can and should be implemented in ways to complement and reinforce each other. DOE is working with EPA and industry to promote AFVs that will meet the clean fuel fleet vehicle requirements.

It should be noted, however, that there are important differences between the two programs. Significant differences between the two programs include: (1) the primary goal of the EPA program is to significantly improve air quality through reduced emissions of pollutants while the primary goal of the DOE program is to strengthen national energy security by reducing dependence on imported oil; (2) the lists of fuels enumerated in the definitions of "clean fuel" under section 241 of the Clean Air Act and of "alternative fuel" under section 301 of the Energy Policy Act of 1992 are not identical, and the Department's rulemaking discretion to add to the section 301 list is limited by stringent statutory standards; (3) the EPA program applies to fleets as small as ten vehicles while the EPACT fleet program covers fleets of 20 or more vehicles provided that the covered fleet operates 50 or more vehicles nationwide; (4) the EPA program applies to light-duty motor vehicles (up to 8,500 gross vehicle weight (GVW) rating) and heavier duty motor vehicles (up to 26,000 gross vehicle weight rating) while the DOE program applies only to light-duty motor vehicles (up to 8,500 GVW); (5) the States will administer the EPA program while DOE will directly administer the EPACT program; and (6) the EPA program applies only to fleets in 22 ozone or carbon monoxide (CO) non-attainment areas[23] (less than half appear likely to implement such programs at this time) while the DOE program applies to fleets in approximately 121 areas, including both non-attainment and attainment areas.

[23] All these areas have a population of 250,000 or more according to the 1980 census. The ozone non-attainment areas are classified as serious, severe, or extreme; the CO non-attainment areas have a CO design value of 16 parts per million (ppm) or higher. Areas are able to opt-out by creating equivalent emissions reductions through their State Implementation Plans; two areas have opted into the Clean Fuel Fleet Program.

V. ACTUAL AND POTENTIAL ROLE OF REPLACEMENT FUELS AND AFVs

The preliminary estimate of replacement fuels used in 1998 in the U.S. is about 4.3 billion gallons gasoline equivalent (or 3.6 percent of total highway gasoline use). Of this, 3.9 billion equivalent gallons was oxygenates (3.4 percent of gasoline) and 334 million equivalent gallons was alternative fuel used by AFVs (0.3 percent of gasoline). The results of phase one of DOE's study of the feasibility of reaching the goals suggested by section 502(b) indicate that the potential use of replacement fuels sustainable by the market could be as high as 30 to 40 percent in 2010 under various scenarios. In order to reach such levels of alternative fuel use, however, major transitional impediments would have to be overcome, including changes in relative fuel/vehicle prices to consumers.

Actual Role of Replacement Fuels and AFVs

In response to the "Replacement Fuel Demand and Supply Information" required by EPACT section 503, the Energy Information Administration (EIA) publishes a series of annual reports entitled *Alternatives to Traditional Transportation Fuels*. According to EIA, 395,625 AFVs were in use in the U.S. in 1998, with 418,128 expected to be in use in 1999. Of the 1998 inventory, 269,000 were fueled by LPG; 85,730 by CNG; 21,578 by M85; 11,743 by E85; and 5,824 by electricity; with the remainder LNG, M100, and E100. The proportions of the various AFVs by fuel type are shown in Figure 3. Around 71 percent were owned by the private sector, 23 percent owned by State and local governments, and 6 percent owned by the Federal Government (Figure 4). Figure 5 illustrates the use of alternative fuels, oxygenates (ethanol and MTBE used in gasoline[24]), and total replacement fuels[25] as a percentage of total vehicle gasoline used in the U.S. While oxygenate use has increased from under 1.7 percent in 1992 to 3.4 percent in 1997, alternative fuel use has increased slightly and hovers around 0.2 percent. Total replacement fuel use reached 2.8 percent in 1997 with slight decreases forecasted for 1998 and 1999. EIA projects that in 2010 total alternative fuel use (EPACT and non-EPACT) will total 3.9 percent of gasoline use. If oxygenate use remains at its current percentage, total replacement fuel use by 2010 would be between 7 and 8 percent of total gasoline use.

---

[24] A very small amount of oxygenates similar to MTBE have been used and are included as MTBE.

[25] The EIA data for replacement fuels exclude natural gas liquids (NGLs - butane, pentane, and some heavier hydrocarbons collected as condensate during natural gas production, transmission, and storage) blended into gasoline. Some blended NGLs could be interpreted to be LPG, which is included in the EPACT definition of replacement fuels, while other NGLs are outside the EPACT definition.

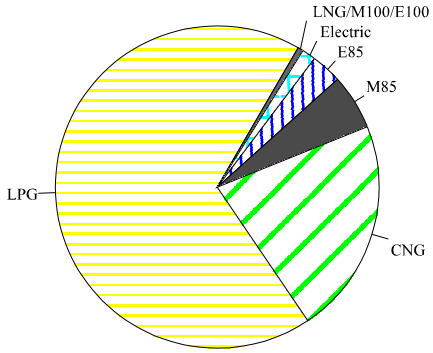


Figure 3. 1998 AFV Inventory by Fuel Type
Source: EIA

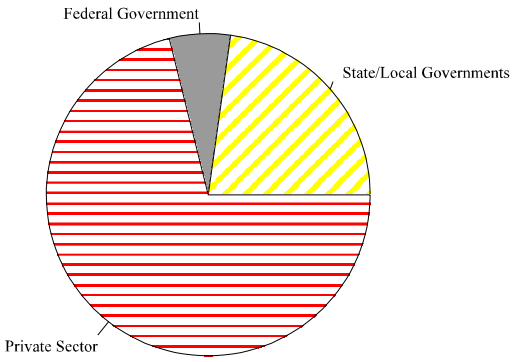


Figure 4. 1997 AFV Inventory by Owner
Source: EIA

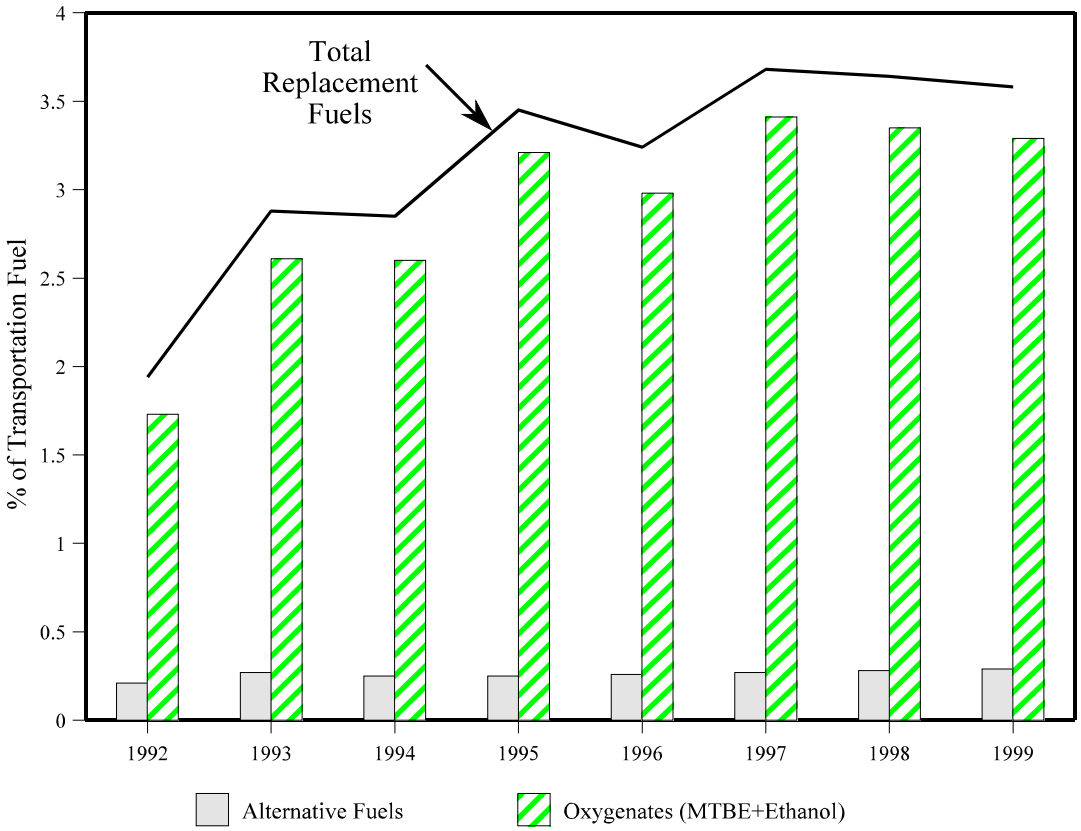


Figure 5. Alternative Fuels and Oxygenates Relative to Vehicle Gasoline Use
Source: *Alternatives to Traditional Transportation Fuels 1997*, Table 10, Energy Information Administration

Potential Role of Replacement Fuels and AFVs

DOE modeling indicates that the potential role of replacement fuels and AFVs in the U.S. is large. Based on underlying costs, it appears that the market could sustain a significant market share of replacement fuel use in 2010. The share of replacement fuel use could even approach or surpass the 30 percent goal called for in 2010 under scenarios that entail higher oil prices and strong incentives for alternative fuels. Even in light of the successful technology development and voluntary programs, however, the U.S. does not appear to be on the path to such large-scale replacement fuel use, and appears unlikely to approach such market shares without significant changes in relative prices to consumers. The unfavorable cost structure reflects current market conditions, but more importantly the transitional costs and other impediments associated with building distribution and retailing infrastructure for alternative fuels and achieving economies of scale in AFV production. Even with more favorable costs, considerable perceptual and logistical barriers would have to be overcome.

Other countries' experience with alternative fuel vehicle programs shows that favorable consumer economics is critical but not in itself sufficient for achieving large alternative fuel market shares. The U.S. approach embodied in EPACT is somewhat unique among world programs in its reliance on government-industry research and development partnerships and fleet AFV requirements to help overcome barriers and catalyze initial infrastructure. Fleet AFV use by itself will be insufficient to achieve large alternative fuel market share. Alternative fuel use by EPACT covered fleets, even with the contingent mandates for private and local government fleets, is unlikely to provide more than about 1.5 percent replacement fuel use. Large volumes of AFVs would have to be acquired by the motoring public in order for replacement fuels to reach high market shares. In order to reach 30 percent replacement fuel use by 2010, AFV sales would have to reach approximately 30 to 40 percent of new vehicle sales by year 2000 and stay in that range through 2010. Such rapid market penetration is beyond even the typical pattern for auto industry market introduction of conventional new models or technologies. AFV penetration conforming to more typical market introduction would be consistent with replacement fuel use of 30 percent sometime around 2020 (if market conditions were favorable and transitional impediments were overcome).

The potential for replacement fuel use through substantially greater blending of oxygenates in conventional fuels was not evaluated within the scope of this study, though it could also be considerable. Such blending could occur through more widespread blending of oxygenates geographically or possibly through higher blending levels. Energy security benefits, economic costs and benefits, and environmental implications should be studied further in the future.

Market Potential: Analytical Results to Date

DOE has assessed the potential roles of replacement fuels and AFVs most systematically in part one of its study performed under EPACT section 502(b), which required DOE to evaluate the

technical and economic feasibility of displacing 10 percent of U.S. motor fuel use by year 2000 and 30 percent by 2010 (published as *Technical Report Fourteen*).[26]

With regard to the year 2000 goal of 10 percent LDV replacement fuel use, although the study projected little increase in use of alternative fuel vehicles beyond the mandated fleet usage by year 2000, it found that the 10 percent goal could be met if NGLs blended with gasoline are counted as replacement fuels (along with oxygenates).[27]

For year 2010, the study simulated a world market based on the underlying economic costs of production, distribution and use of different fuels, and the consumer advantages/disadvantages associated with each. In effect, it assumed that the necessary infrastructure, production capacity, and distribution networks were in place for those fuels that are inherently competitive. It also assumed that alternative fuel vehicles were available at the lower costs associated with large-scale production levels, rather than the higher costs of initial small-scale production runs. In other words, it assumed that transitional problems are solved and that the advantages of "incumbency" currently enjoyed by gasoline (and diesel) are neutralized.

Technical Report Fourteen is based on long-run equilibrium analysis using DOE's Alternative Fuels Trade Model (AFTM) for year 2010. The AFTM determines prices and quantities that balance the interrelated world oil and gas markets based on projected supply, demand, and conversion costs. The model estimates changes in fuel markets that could economically occur by 2010 given a well-developed infrastructure for alternative fuels. Variables estimated by the model include fuel prices, fuel volumes used, fuel imports, international trade flows, and greenhouse gas emissions. The model also estimates the costs and benefits of alternative fuel use.

The report focused on the economic and environmental implications of substituting alternative transportation fuels for 30 percent of conventional gasoline and diesel fuel used in LDVs in year 2010. The fuels examined were: compressed natural gas (CNG), liquefied petroleum gases (LPG - principally propane), methanol from natural gas, ethanol from cellulosic feedstocks, and electricity (i.e., electric vehicles).

Technical Report Fourteen evaluated fuel substitution by privately-owned LDVs that are not part of large fleets. EPACT mandates some level of AFV use by Federal, State, fuel provider and possibly private and local government fleets of 20 or more vehicles (operated by entities that control 50 or more vehicles). Several State programs also mandate AFV and/or replacement fuel use in both fleets and personal use vehicles (e.g., the California zero emissions vehicle (ZEV)

---

[26] U.S. Department of Energy, Office of Policy. *Assessment of the Costs and Benefits of Flexible and Alternative Fuel Use in the U.S. Transportation Sector, Technical Report Fourteen: Market Potential and Impacts of Alternative Fuel Use in Light-Duty Vehicles: A 2000/2010 Analysis*, January 1996.

[27] EIA, on the other hand, does not classify blended NGLs as replacement fuels in its section 503 reports or other publications. If NGLs, representing about five percent of light-duty motor fuel, are not counted, it appears unlikely that the ten percent goal would be met. Treatment of NGLs would not necessarily have major implications for the section 502(b)(2)(B) goal of 30 percent replacement fuel use in 2010.

mandate).[28] Alternative fuel use by private and local government fleets was estimated separately (outside of the model) as part of the non-market fleet population, calculated as if the fleet mandates of EPACT section 507(b) were imposed, although existence of the statutory conditions for those mandates has yet to be determined. The report, thus, primarily dealt with the feasibility of EPACT 30 percent replacement fuel goal for 2010 in the market for personal cars and light trucks.

Results from the study indicated that displacing 30 percent of light-duty motor fuel use by 2010 was technically feasible given the assumptions regarding future oil prices that prevailed during the 1994-1996 time frame.[29] Analysis of vehicle production decisions and the growth in the vehicle stock indicated that up to 100 million alternative fuel vehicles (or about half of the total stock of LDVs) could be in use by 2010. If demand were sufficiently great, vehicles could be produced in large enough numbers to achieve significant economies of scale. In addition, the fuels could be produced and distribution systems put in place to make the fuels widely available throughout the U.S.

The report estimated that the market could support replacement fuel use at 30 percent or more of light-duty motor fuel in 2010, and perhaps this level could ultimately be even higher. The percentage varied for different scenarios analyzed.

The alternative fuels/AFV combinations that appeared to be most economical are methanol and propane. The combined vehicle and fuel cost for propane vehicles was estimated to be less than that of all other fuels, and methanol was projected to have both favorable long-term production costs and competitive vehicle costs.

Neither CNG nor ethanol appeared to be competitive in the broad private vehicle market. Ethanol use was limited because of its high cost of production. CNG, on the other hand, which is less expensive than conventional fuels on a gasoline equivalent basis, was disadvantaged principally because of the high incremental vehicle cost. Lengthy and frequent refueling was an additional impediment to widespread CNG use. On the other hand, in scenarios that include the current ethanol tax credits, ethanol use rose to 40 percent of alternative fuel use, with methanol and LPG use dropping correspondingly.

---

[28] Originally scheduled to begin in 1998 requiring automakers to sell ZEVs in numbers equal to 2 percent of their California vehicle sales, implementation of the mandate was postponed by the California Air Resources Board to begin in 2003 with a requirement of 10 percent EV sales.

[29] *Technical Report Fourteen* results are based, in part, on underlying assumptions about future fuel costs (particularly oil/gasoline and ethanol) that were used as inputs into the model. Those projections of future oil prices, however, were made during the 1994-1996 time frame. Current projections of future oil prices have a lower trajectory. If current oil price projections were employed within the *Technical Report Fourteen* modeling framework, the essential conclusion that 30 displacement is economically viable in the long run, if transitional barriers were removed, is unlikely to still be valid. Current transitional modeling results, drawn from the Transitional Alternative Fuel Vehicle (TAFV) model and discussed in the following, indicate lower replacement fuel use than shown in *Technical Report Fourteen* due, in part, to projected oil price trajectories that are lower than those prevailing in the 1994-1996 time frame.

Electric vehicles (EVs) were not used in any scenario above their mandated usage of 0.09 million barrels per day gasoline equivalent (based on ZEV mandates in California, New York, and Massachusetts). This is because of the high incremental cost (estimated at $5,000 with future large-scale production, higher for the foreseeable future) and performance characteristics of electric vehicles. It would take a major breakthrough in EV technology to make EVs competitive in the private vehicle market.

The study also considered the effect of petroleum fuels displacement on fuel imports. Despite the decline in oil imports brought about by the increased use of alternative fuels, there was almost no decline in total fuel imports. This was because virtually all of the vehicular methanol, and much of the LPG, would likely be imported. Propane use would result in partial displacement of imported crude oil, but about 40 percent of the vehicular propane would be imported. Furthermore, much of the propane that was not directly imported could still result in an indirect increase in petroleum imports as other domestic industries previously using propane switch to other, imported, petroleum products. Nonetheless, it is possible that substantial advantages could be gained from the diversification of fuels and sources and from greater flexibility in fuel choice, even if alternative fuels might be imported.

CNG use would displace some petroleum. Because of substitution elsewhere in the economy, a given volume of CNG used would displace a smaller volume (about half) of petroleum on a Btu equivalent basis. CNG use as a motor fuel would lead to some increase in domestic natural gas prices for other uses, including residential heating.

Greenhouse gas emissions were not significantly lowered by alternative fuel use unless a significant incentive to use lower GHG fuels was also imposed. In this case, GHG reductions were achieved by the use of a renewable fuel such as ethanol from cellulose or methane from anaerobic decomposition.

In long-run equilibrium, *Technical Report Fourteen* projected that making alternative fuels and alternative fuel vehicles available would provide a net annual economic benefit of up to $10.3 billion in 2010.[30] This level of gain would be achievable in the reference case with tax neutrality. Much of this benefit ($4.2 billion) consisted of an increase in consumer satisfaction from the availability of new classes of vehicles and less expensive fuels; the remaining $6.1 billion reflected dollar cost savings from alternative fuel use, mainly through reduced cost of fuel imports. There could also be significant environmental benefits: up to $3.7 billion per annum. However, there could be significant transition costs that must be weighed against these gains. Transition costs were not included in this preliminary analysis but are being estimated by DOE in an ongoing study described below. Such costs include potentially higher fuel production, fuel distribution, and vehicle costs, etc., which will likely exist in the transitional years when AFVs begin to penetrate the LDV market. The report concluded that, while a free market could sustain a large volume of alternative fuel use, it does not appear at present that the market will move

[30] The level of net annual economic benefit projected by *Technical Report Fourteen* would also be reduced if current projections of oil prices, relative to those that prevailed during the 1994-1996 time frame, were used.

toward such a scenario without either Government action to affect the availability of both fuels and vehicles or a sharp increase of oil prices relative to replacement fuel prices.

Transition Analyses

Although not specifically requested by section 506 of EPACT, DOE is attempting to provide as meaningful analyses as possible of the likely path between the current replacement fuel use and the potential use described in *Technical Report Fourteen*.

DOE is undertaking a transition analysis based on a dynamic market model of AFV use to support DOE rulemaking determinations under EPACT title V and its examination of the goals called for by section 504. This model can be used to forecast actual use of alternative fuels by AFVs (including dual-fuel AFVs), impacts from EPACT programs and other programs and policies, response of fuel providers, and infrastructure and any spillover AFV/alternative fuel use from fleets to private households.[31] The transition modeling study considers the feasibility of the EPACT fuel replacement goals, and the efficacy of various policies to promote alternative fuel use. It uses the Transitional Alternative Fuels Vehicle (TAFV) Model, which simulates the introduction and cost of alternative fuels and vehicles over the time period of 1996 to 2010. It is designed to examine the *transitional* period of alternative fuel and vehicle use, considering possible barriers related to infrastructural needs and production scale. It accounts for dynamic linkages between investments and vehicle and fuel production capacity, tracks vehicle stock evolution, and represents the effects of increasing scale and expanding retail fuel availability on the effective costs to consumers. Fuel and vehicle prices and choices are endogenous. As a dynamic transitional model, it can help to assess what may be necessary to achieve mature, large-scale, alternative fuel and vehicle markets, and what it may cost. The policy cases considered include fleet vehicle purchase mandates, fuel and vehicle subsidies, and tax incentives for low greenhouse gas emitting fuels.

The transitional cases explored employ newer DOE (AEO98) projections for future gasoline prices and fuel costs than were used in *Technical Report Fourteen*. As a result, alternative fuels are less able to garner market share than in the long-run analysis of *Technical Report Fourteen*. In AEO96 the projected real gasoline price rises at 0.9 percent per year through 2010, while in AEO98 it was revised down to a nearly flat trajectory (rising by only 0.2 percent/annum).[32] Second, the ethanol tax credit, while now extended through 2007, declines somewhat in nominal terms, and is assumed to decline even faster in real terms, given a 3 percent inflation rate over the forecast horizon. In previous analyses the ethanol tax credit was assumed to maintain its real value, at least through 2001, and potentially longer if extended. Finally, the costs of producing ethanol from cellulosic biomass were re-estimated given DOE's newer understanding about the

---

[31] For additional discussion of transition issues, see "Alternative Fuels and Vehicles: Transition Issues and Costs," Mintz, Marianne, and Singh, Margaret K.

[32] Bowman, David, Paul Leiby, and Jonathan Rubin 1998. "Updates to the TAFV with the AEO98," TAFV Model Technical Note, Draft, Revision 1, June 23.

technologies and the economics of ethanol production, and found to be about $0.17/gallon higher than previously believed.[33]

Transitional Analysis Result Highlights

Below are some important insights from the transitional analyses completed using the TAFV model.[34]

1. Overall, the transitional market barriers to significant alternative fuel and vehicle use are substantial. In the absence of any new policy initiatives, it may be difficult for the alternative vehicle and fuel markets to get started. The base (current policy) case yields almost no AF and AFV penetration. For the AEO98 base oil price path, current policies (i.e., current EPACT fleet mandates, fuel taxes, and CAFE credits for AFVs), appear inadequate to induce any large-scale alternative fuel use, or any AFV purchases beyond the minimum mandated by the law.

2. More remarkably, if the DOE/EIA base case oil price projections from AEO98 hold true, even some substantial new AFV/AF incentives may have only limited effect. For example, the continuation of the ethanol tax credit beyond 2007 may be inadequate to induce ethanol (or other) AF use. This is assuming that the ethanol tax credit is specified in nominal terms, and is allowed to decline in real terms each year with 3 percent inflation.

3. A long-run, no-barriers case was examined to assess what AFV/AF penetration might be expected if there were no transitional barriers to their introduction, other than the usual gradual turnover of vehicle stock. The no-transitional-barriers case explores what would happen if alternative fuels and vehicles were produced at large-scale costs, and fuel availability and vehicle diversity pose no effective cost to consumers. The long-run, no-barriers case projects a 15 percent displacement of gasoline by alternative fuels in the year 2010, including 8.4 percent displacement by blends and only a 6.5 percent displacement by neat alternative fuels (including M85, CNG, and LPG). This result, which reflects the bedrock competitiveness of alternative fuels in a mature market, is much lower than the figure estimated in *Technical Report Fourteen*, and lower than the 14.4 percent neat fuel penetration achieved in earlier TAFV analyses using 1996 fuel price projections. While the long-run, no-barriers gasoline displacement under 1998 base prices is 15 percent, other fuel price assumptions increase this displacement level. With the AEO98 High World Oil Price projection, petroleum displacement rises to 18 percent by 2010. If lower LPG costs are also available, then in the absence of transitional barriers, we find that petroleum displacement would be 25 percent. Thus, the TAFV model using fuel price assumptions close to those used in *Technical Report Fourteen* finds similar levels of petroleum displacement. The

[33] Bowman, David and Paul Leiby 1998. "Methodology for Constructing Aggregate Ethanol Supply Curves," TAFV Model Technical Note, Draft, Revision 3, Oak Ridge National Laboratory, August 24.

[34] Leiby, Paul and Jonathan Rubin, 1998. "The Alternative Fuel Transition: Draft Final Results from the TAFV Model of Alternative Fuel Use in Light-Duty Vehicles 1996-2010," February 27.

bottom line, however, is that under the 1998 revised gasoline and alternative fuel cost projections, alternative fuels are just not as competitive.

4. The incentives considered that are most effective in inducing the displacement of petroleum are a low-greenhouse gas tax credit policy and the continued ethanol tax credit policy. Both of these policies rely on substantial subsidization of ethanol and other low greenhouse gas fuels. Given base case fuel price projections, these policies are not sufficient to induce additional AF penetration. Given high world oil prices (HWOP cases), however, these policies can be effective, particularly if the tax credits are adjusted for inflation to maintain their present value. Given HWOPs, the low-greenhouse gas tax credit induces petroleum displacement from 9.3 percent to 11.3 percent by 2010. If, in addition, the low-greenhouse gas tax credit is also inflation-adjusted 22 percent of petroleum can be displaced by 2010. The continued ethanol tax credit policy case is slightly less effective since it only targets ethanol. Nonetheless, it is able to induce a 16 percent displacement of petroleum if the tax credit is maintained at its present value.

These results lead to several observations. First, in a market economy where vehicle manufacturers, fuel suppliers, and consumers all make independent decisions, the efficacy of government policies to reduce the dependence of the U.S. transportation sector on petroleum is highly dependent on the world price of petroleum. Second, the penetration of AFs and AFVs depends on the fuel retail infrastructure, the extent of adoption of AFVs, and other transitional barriers. Absent new government policies to reduce these transitional barriers, it is likely that the U.S. will not achieve EPACT's 2010 displacement goals. Governmental policies can effectively reduce these barriers and can allow alternative fuels to compete in the marketplace with gasoline. However, given recent low petroleum prices, the policies required to meet the 2010 displacement goal will have to be substantial and sustained.

AFV Penetration Needed to Reach the 10 and 30 Percent Goals

The EPACT goals are based on the percent of motor fuel used in transportation. For purposes of this analysis, motor fuel use will be defined as the total motor fuel used by light-duty vehicles according to EIA. Figure 6 illustrates the projection of total light-duty motor fuel use through 2010, as well as the 10 and 30 percent goals in the years 2000 and 2010, respectively. Total light-duty motor fuel use is projected to rise from 13.5 quads in 1995 to 14.3 quads in 2000, 15.1 quads in 2005, and 15.5 quads in 2010.

The EPACT goals to displace 10 percent of transportation fuels in the year 2000 and 30 percent in the year 2010 will require that a large number of light-duty AFVs be in operation. Figure 7 illustrates the range[35] of light-duty AFVs that would have to be sold annually in order to meet the EPACT goals for motor fuel displacement (assuming that 4.0 percent of light-duty motor fuel

[35] The range is due to varying estimates of new vehicle sales, fuel efficiency, and vehicle scrappage rates in the future. The upper bound represents the most conservative combination of these variables while the lower bound represents the most optimistic combination.

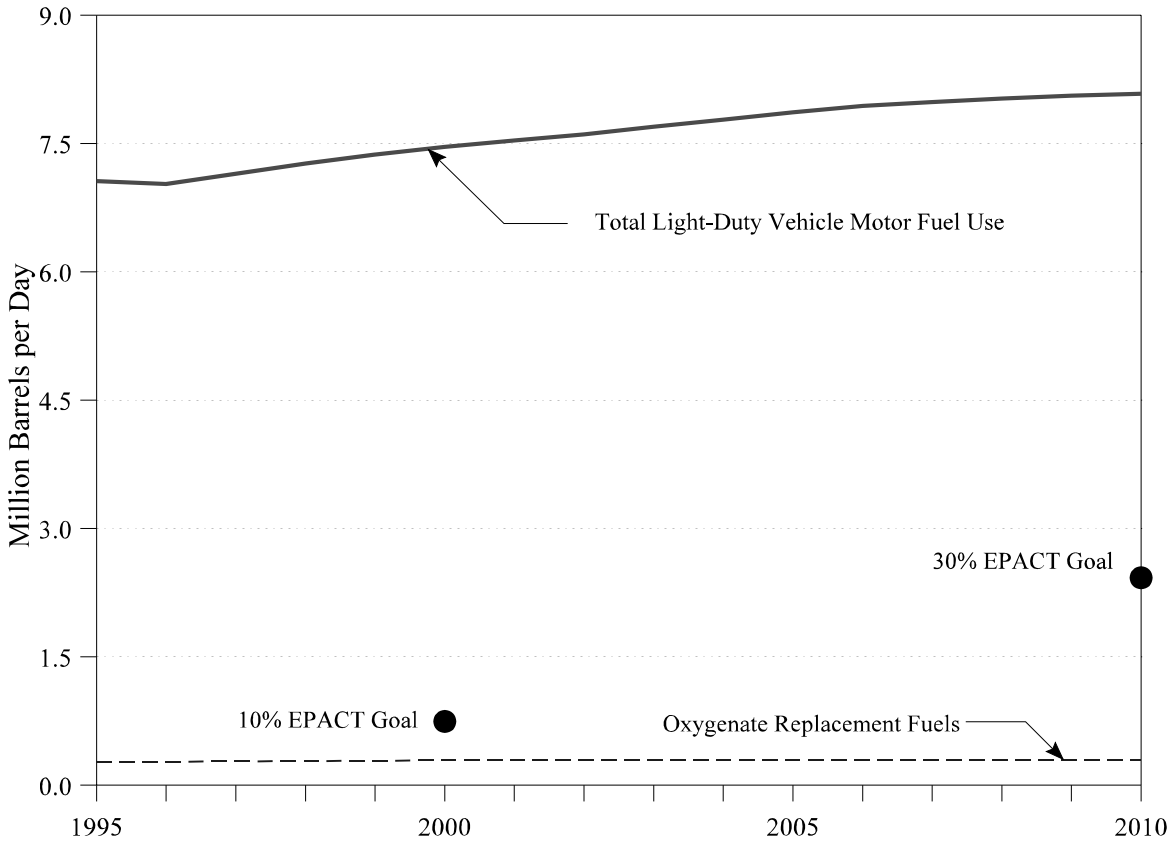


Figure 6. Total Light-Duty Vehicle Motor Fuel Use and EPACT Goals
Source: EIA

gasoline is oxygenate replacement fuels and assuming that all of the AFVs projected are operated on alternative fuels all of the time).

As Figure 7 shows, a very high rate of AFV sales is necessary to meet the 10 percent goal in the year 2000 (4 percent of the 10 percent being met with oxygenates blended into gasoline and 6 percent being met with alternative fuels used in AFVs). This very rapid build-up is required to get enough AFVs in service to cause the required amount of fuel consumption to occur. For example, analysis shows that AFV sales in the three year period 1998 to 2000 would have to increase by about 1.5 to 1.9 million per year. We now know that such a dramatic sales increase would be historically unique and did not happen. To put this sales increase into perspective, the entire production of Ford passenger cars in 1996 was slightly more than 1.4 million. Figure 8 illustrates AFV sales in terms of the percentage of total light-duty vehicles sales. As Figure 8 shows, AFV sales must grow to between 35 and 40 percent of total light-duty sales to meet the 2000 goal and stay in the range of 30 to 38 percent to build an AFV population sufficiently large to meet the 2010 goal. Figure 8 illustrates how the AFV population would grow through 2010 based on the sales curve of Figure 6.

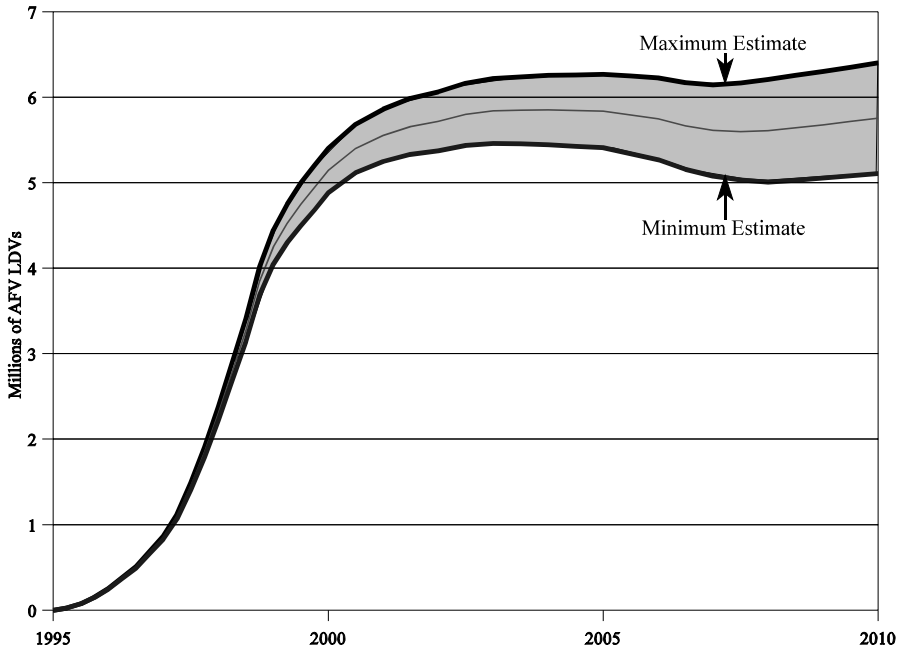


Figure 7. New Light-Duty AFV Sales Required to Achieve EPACT Goals

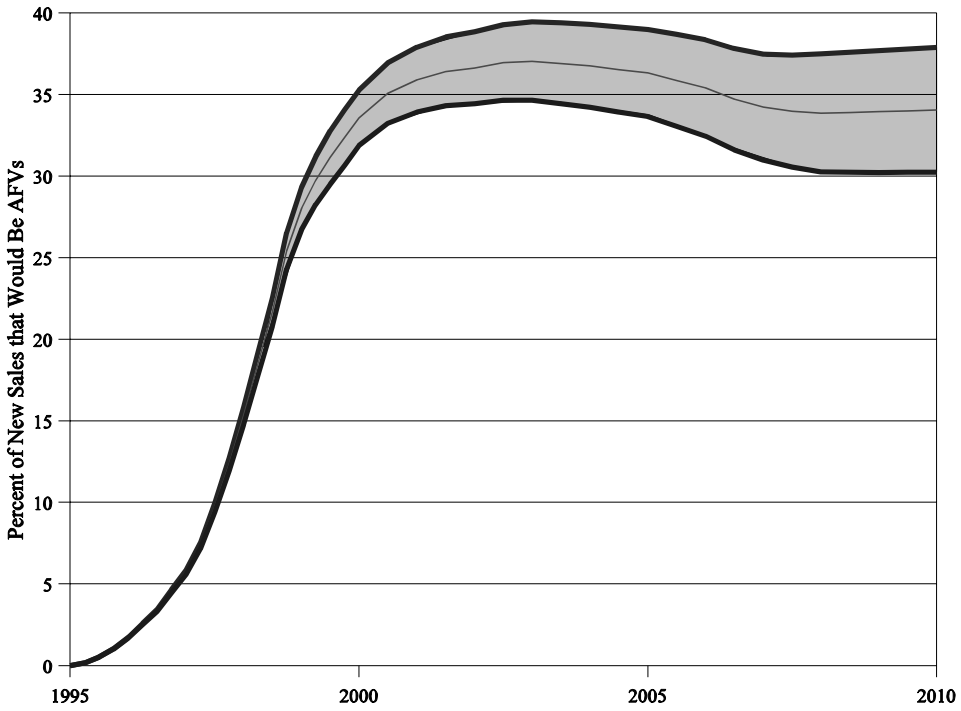


Figure 8. AFV Sales to Meet EPACT Goals as a Percentage of New Light-Duty Vehicle Sales

Figure 9 vividly illustrates why AFV sales would have to increase very rapidly and stay at a high level through 2010 to meet the 30 percent EPACT goal. As Figure 9 shows, the AFV population must grow steadily from approximately 1998 through 2010 in order to build a vehicle population sufficiently large to consume 30 percent of the projected amount of light-duty motor fuel in 2010. AFV sales as a percent of total new light-duty vehicle sales level out in the mid-30s to achieve 30 percent displacement because total light-duty motor fuel is projected to increase each year from 1996 through 2010, but vehicle fuel efficiency is also projected to increase each year, requiring more vehicles to achieve a given fuel displacement than the average older vehicle in the conventional LDV population.

The estimated amount of light-duty fuel displacement by the AFV population illustrated in Figure 9 is shown in Figure 10. (The initial amount of replacement fuel use in 1995 is due to oxygenates in gasoline and existing alternative fuel use by light-duty vehicles.[36]) The slow increase in fuel displacement illustrated in Figure 10 is due to the time needed to build an AFV population that has significant fuel consumption relative to the conventional LDV population. After the AFV population is established and growing at a steady pace, the amount of alternative fuel consumed also grows at a steady pace.

The rapid market penetration depicted in Figure 8 and Figure 9 is beyond even the typical pattern for auto industry market introduction of conventional new models or technologies. An AFV acquisition scenario was also considered that simulates a more gradual phase-in of AFVs over the coming 25 years (the "Reference Growth" scenario). Such a scenario for AFV implementation based on a slower initial growth rate of AFVs is illustrated in Figure 11, Figure 12, and Figure 13. This scenario includes growth of AFV sales in several distinct phases. In the first phase (years 1995 through 2000), AFV growth doubles every year, going from approximately 30,000 to 500,000 sales per year, representing production of AFVs across several manufacturers and model lines.

The sales increase in this time period, however, never exceeds 250,000 vehicles per year. In the period from 2001 through 2005, AFV sales increase by 50 percent per year, representing a period of sustained high-growth of AFVs sales. In the year 2005, total AFV sales would be 3.9 million. After the period of sustained high-growth, AFV sales growth in the period of 2005 through 2010 is assumed to decrease steadily so that by 2011 sales of AFVs remain at a constant 32 percent of total LDV sales (Figure 12). If AFV sales are then constant from 2011 through 2020 at 32 percent of all LDVs, the AFV population in 2020 (ten years later than the EPACT 30 percent goal) will be large enough so that 30 percent of LDV motor fuel will be alternative fuel plus oxygenates in conventional vehicle fuel (Figure 13). (Note that the initial fuel displacement in Figure 13 is due to oxygenate and alternative fuel use in 1995.[37]) In this scenario, the original

---

[36] "*Alternatives to Traditional Transportation Fuels, 1993*" Energy Information Administration, DOE/EIA-0585(93), January 1995.

[37] Range due to varying estimates of new vehicles sales, etc. (see footnote 7).

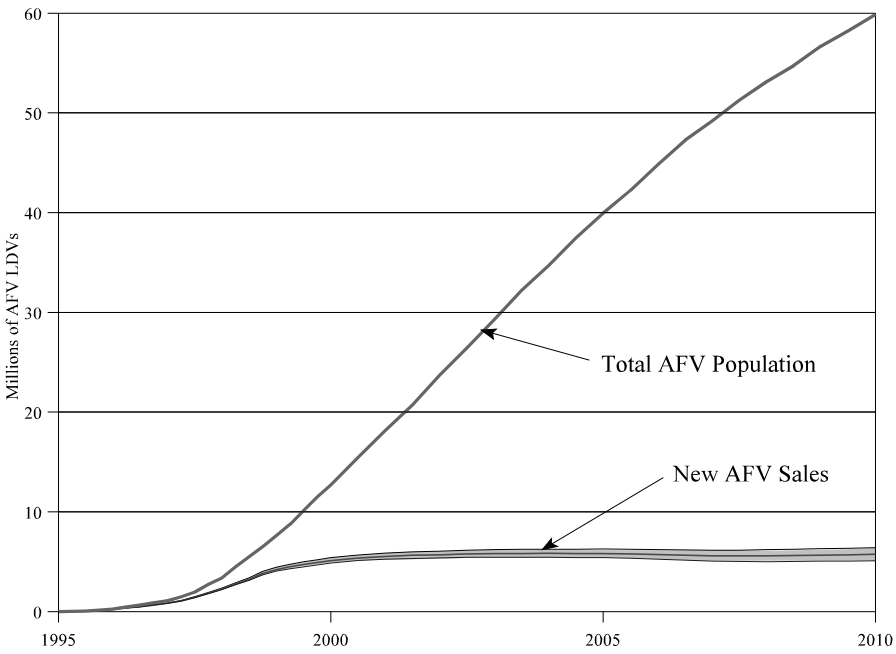


Figure 9. AFV Sales and Population to Meet EPACT Goals for Motor Fuel Displacement

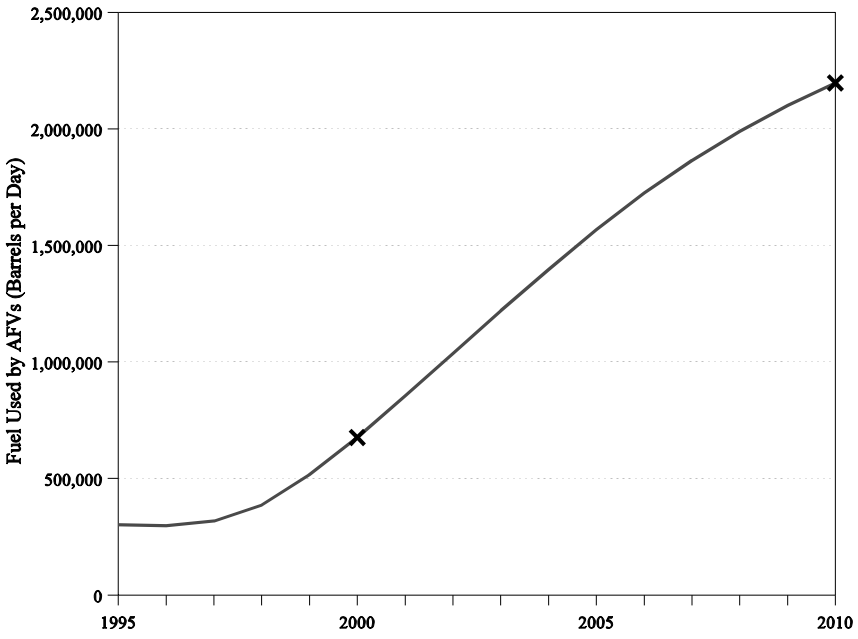


Figure 10. Replacement Fuel Energy Use by AFVs to Meet EPACT Goals

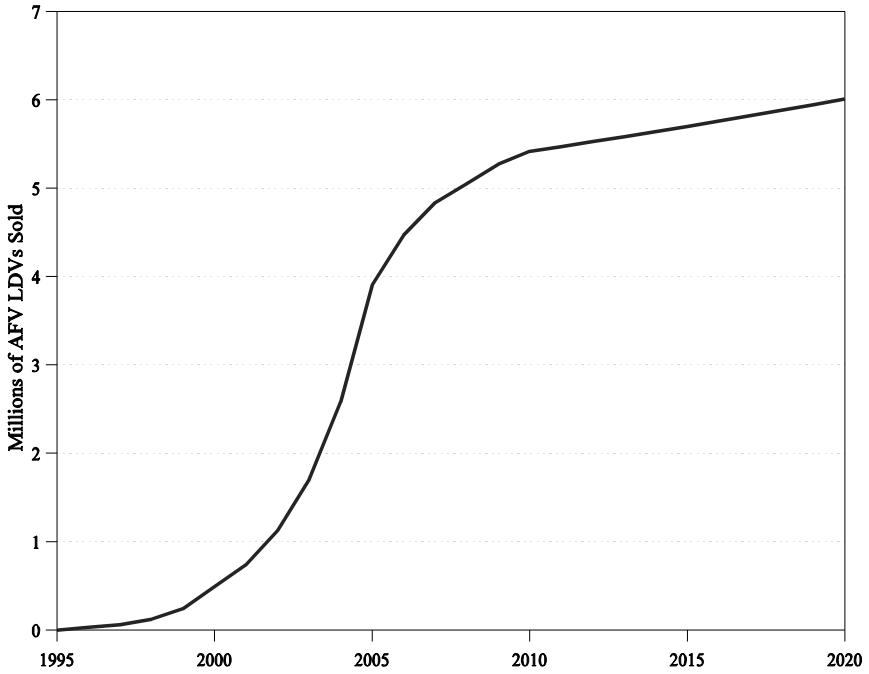


Figure 11. Projection of AFV Sales under the Reference Growth Scenario

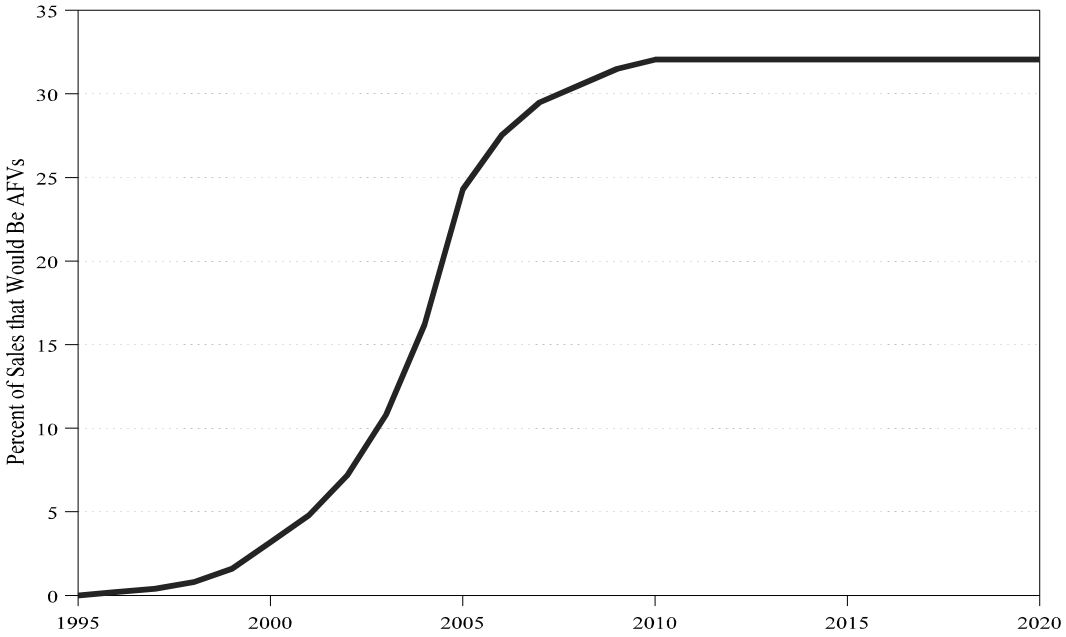


Figure 12. AFV Sales as a Percentage of Total New Light-Duty Vehicle Sales - Reference Growth Scenario

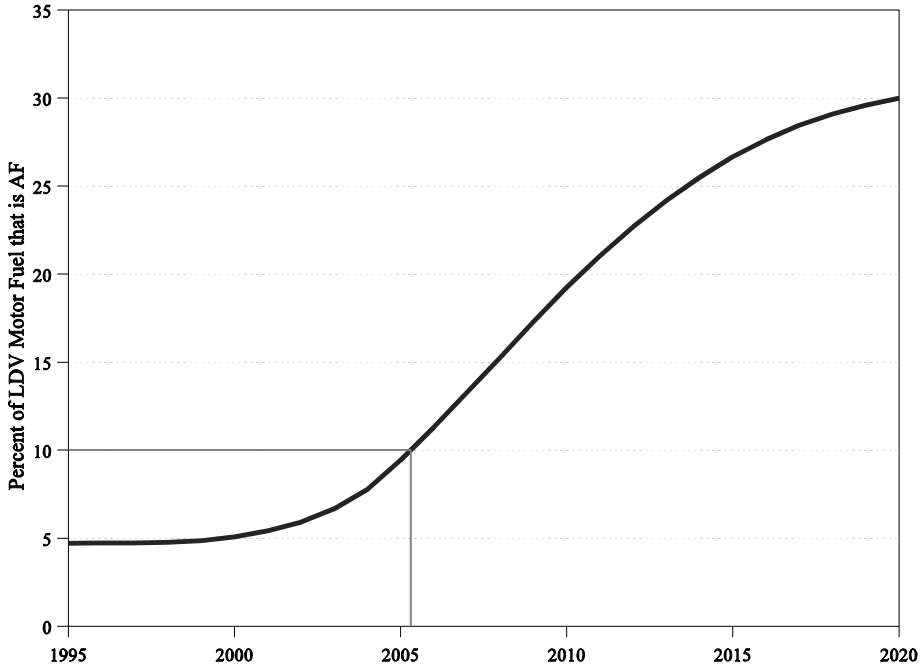


Figure 13. Fuel Displacement as Percent of Total LDV Motor Fuel under the Reference AFV Growth Scenario

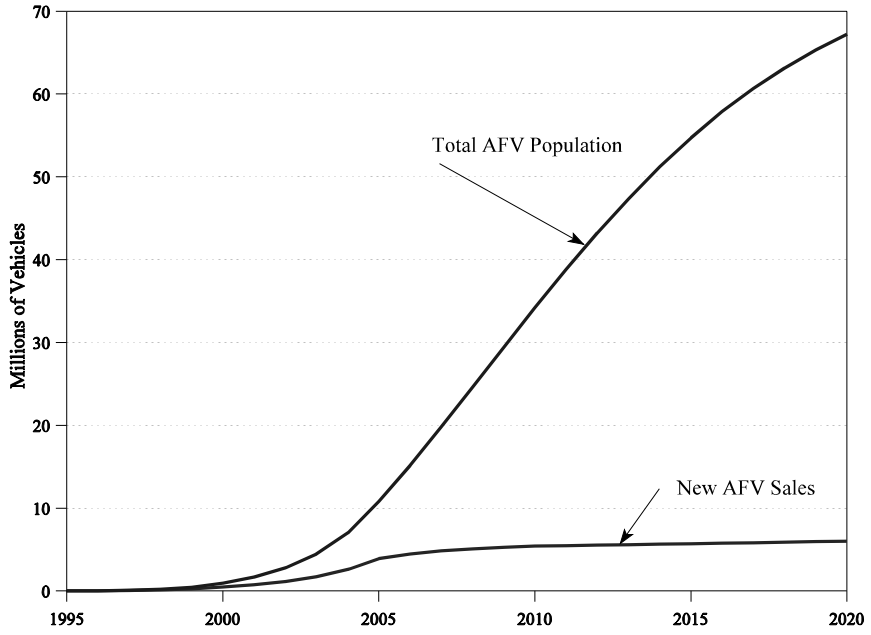


Figure 14. AFV Sales and Population for the Reference Growth Scenario

10 percent replacement goal is essentially met in 2005, five years later than the original EPACT goal date. This scenario ends up with a larger population of AFVs (67 million, Figure 14) than the previous calculation of AFV population to meet the EPACT goals (60 million, Figure 9). The difference is due to the fact that the LDV population in the U.S. is projected to continue to grow, and that new LDVs will be more fuel efficient than previous ones, requiring more new AFVs to achieve the same level of fuel consumption as older vehicles.

To meet the 10 and 30 percent goals in EPACT requires a very rapid increase in vehicle sales followed by sustained sales at a high level without large increases in sales growth. This type of market behavior is not typical. More likely would be slower initial sales increases followed by long periods of sustained sales growth. Without some constraint on sales, and assuming economic reasons for purchasing AFVs, it is difficult to envision a scenario that would result in rapid growth that levels off when 30 percent fuel displacement is achieved. More readily conceivable would be that the 30 percent fuel displacement level would be just one point along a path to some higher equilibrium of AFVs versus conventional vehicles. (Alternatively, if AFV growth were to reach a maximum of only 30 percent fuel use, the time to reach 30 percent would be more gradual.) The reference sales growth scenario has this characteristic in that sales growth is positive when 30 percent fuel displacement is reached on the way to higher AFV sales in the future.

This reference growth scenario is believed to be generally more representative of new vehicle market introduction than the growth paths reflecting the EPACT goals. Sales growth rates of new technologies such as AFVs, however, typically do not follow such smooth and consistent patterns. Sales may very well increase faster than depicted here at some phase in the process. A major difference between this scenario and the previous ones discussed in this section is that this scenario was not constrained to meet the 10 and 30 percent transportation fuel displacement goals by 2000 and 2010, respectively. The reference growth scenario, however, would still represent an extremely ambitious change for the U.S. economy and society, and it is by no means clear that market conditions and/or policy programs are conducive to embarking on such a path in the near-term.

DOE generated estimates of the numbers of vehicles covered by the various EPACT fleet mandates, and State and local AFV programs, which can be compared and contrasted with the projections of numbers of AFVs necessary to meet the 10 percent and 30 percent goals suggested by EPACT. These estimates indicate that the various Federal and State programs could result in as many as two million AFVs by 2010, counting only those vehicles directly covered by mandatory programs, exclusive of the Clean Cities voluntary program and any spillover effects on non-covered vehicles. (These estimates count private and local government fleets that would be covered by a possible late fleet program under section 507(b).)

The two million AFVs potentially deployed as a direct result of EPACT programs alone could displace approximately 1 percent of transportation fuel use in 2010. In the absence of a specific forcing function, oxygenate use is unlikely to increase significantly beyond the current level of about 2.5 percent. Total replacement fuel use in 2010 is therefore unlikely to exceed 5 percent.

It can be seen from the above estimates that a large gap exists between the AFV penetration likely to result from Federal and State programs by themselves and that necessary to reach or approach the EPACT section 502(b)(2)(B) goal of 30 percent fuel displacement by 2010. At the same time, *Technical Report Fourteen* suggests that the market could support 30 percent fuel use by then. This gap between the level of AFV use that could be supported by the market and that projected to result directly from EPACT mandates raises the questions of whether and how a transition to such alternative fuel use might occur. Could some threshold of use be reached by some of the alternative fuels that would provide for sufficient economies of scale in production and use of the fuels and vehicles, including accessability and convenience of refueling? Would motorists perceive and respond to such a threshold if it is reached? Would the fleet programs provide sufficient critical mass for such economies and accessability and the necessary perceptions on the part of the motoring public? While answers to these questions are not yet available, DOE has considered relevant issues from various perspectives, as are summarized below.

Lessons from International Experience

A number of other countries have implemented policies to promote AFV use in recent decades. To the extent that these programs have been in place for some years, the market reactions could provide valuable indications of likely responses to EPACT programs, not withstanding the considerable differences in the nature of the programs and in the markets themselves.

About one percent of the world's vehicles are powered by alternative fuels. In every country where AFVs have penetrated the market significantly, the national government has played a critical role establishing effective prices for alternative fuels of one-third to two-thirds the prices of gasoline and/or diesel fuels through tax and/or subsidy policies (Canada, New Zealand, Netherlands, Italy, and Brazil). In some cases, subsidies for purchase of new AFVs or conversion of conventional vehicles and/or for refueling infrastructure were also provided (Canada and New Zealand). Even in these five countries, AFV penetration has not been more than 15 percent, except for Brazil. When tax/subsidy policies have been subsequently altered, reducing the fuel/vehicle price differential, conversion of vehicles to alternative fuels and sales of new AFVs have dropped dramatically (New Zealand, Canada, Italy and Brazil). It is clear from the experiences of the countries that have made substantial efforts to convert to alternative fuel use that strong, consistent, and multifaceted national policies are required in order for alternative fuels to have any chance for success, particularly for long-term success.

Strictly in terms of penetration levels, the world's most effective AFV program is clearly Brazil's. There, a combination of tax, subsidy, mandates, and para-statal marketing resulted in an (ethanol) AFV market share of approximately 30 percent, along with another 22 percent gasoline substitution through ethanol blending at the peak levels (1989). Cost effectiveness, however, puts the Brazilian experience in a much different light. The program has often been cited as a substantial contributing factor to runaway inflation and economic disruption. It also resulted in shortages of other fuels (diesel) and even in imports of high-cost ethanol from the U.S. Brazil has had to reduce its subsidy programs as part of its anti-inflationary policies, bringing the whole program into constant reassessment. As relative prices have changed over time, domestic ethanol

producers have shifted their emphasis to other products, such as sugar. In the early 1990s, sales of ethanol vehicles plummeted, and their future market share is difficult to predict.

Aside from Brazil, the Netherlands has the most effective policy. LPG displaces about 15 percent of the gasoline that would otherwise be used by the light-duty fleet. The Dutch policy is tax based; there are no mandates. It has been relatively consistent for two decades; its biggest difficulty lies in keeping the vehicle use tax and the relative gasoline/LPG and diesel/LPG price ratios responsive to changing prices among the factors that together make up the net LPG incentive. Because of lead and lag times, the share of LPG vehicles drifts up and down somewhat, but is not in danger of drifting down so far as to make the fuel delivery infrastructure economically marginal. The policy includes close cooperation with the LPG supply and distribution industry to meet demand, to locate LPG stations at safe locations, and to design and install refueling equipment that is convenient (self-service is allowed), safe, and similar in design to gasoline refueling equipment.

Experience in the other countries shows that governments can cause AFVs, particularly LPG-fueled AFVs, to penetrate the market through combinations of taxes/tax incentives, loan programs, and educational programs. It also shows, however, that, at least over the past 20 years, subsidies continue to be necessary and that governments find it very difficult to maintain the political will to continue the subsidies at large enough levels to generate the desired response. Various countries' experience suggests that the political will to support alternative fuel programs with financial incentives is greatest when oil prices are at peak levels. When the incentives are most critical to sustaining alternative fuel momentum, at the low end of the oil price cycle, governments have often been least committed.

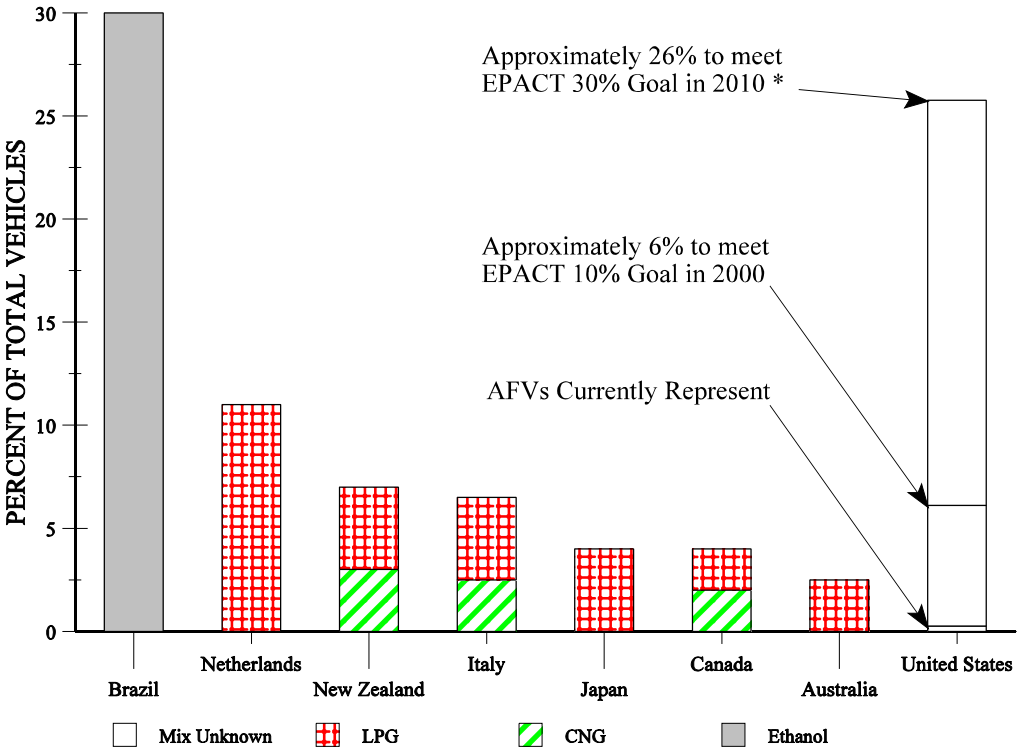
Even where the subsidies have been maintained, lack of governmental attention may cause programs to stagnate, as in Italy. This suggests that the Government role in alternative fuel transition must include many actions beyond the purely economic role of preferential tax treatment for alternative fuels and/or tax credits for AFVs alternative fuel infrastructure.

Penetrations of the various alternative fuels in motor vehicle use in Brazil, the Netherlands, New Zealand, Italy, Japan, Canada, and Australia are shown in Figure 15.

New Zealand's experience with gas-to-methanol-to-gasoline in the 1980s, as well as U.S. experience with synthetic fuels over the same period, shows that large volume subsidies to a small number of large, high-technology companies are politically vulnerable— more vulnerable than a large number of small subsidies, which, it has been shown, are also vulnerable when government budgets get cut. The vulnerability is increased when the technologies used are inadequately proven.

Unlike the countries whose policies have been discussed, the U.S. has chosen a policy route based primarily on Government-industry research and development partnerships, along with

mandates and regulations, with economic incentives playing only a marginal role.[38] Experience with mandated programs is very limited. The international policy experience considered does not address the potential direct impacts of the EPACT fleet mandates. It does suggest that spillover into voluntary use of alternative fuels and AFVs in non-mandated sectors is likely to be determined by the relative economic costs and benefits during each stage of the transition, including (at least for dedicated AFVs) some differential to compensate for future uncertainty and for the operational disadvantages of dedicated AFVs. Merely putting in place novel and limited infrastructure networks is likely to be insufficient in generating high levels of spillover to non-mandated motorists, even in conjunction with cognizance of societal benefits and potential future widespread availability unless and until some change in the overall economics, access, and convenience factors occurs or is perceived to be imminent.[39]



* Difference between AFV and fuel displacement percentages due to oxygenate replacement fuel used

Figure 15. AFVs as Percentage of Total Vehicles in Selected Countries

Source: *Summary of Domestic and International Experience with Alternative Transportation Fuels*, by David E. Gushee.

---

[38] Brazil falls somewhere in-between the U.S. and other country programs, relying on a combination of economic incentives and mandates, principally on the para-statal oil monopoly. Some other countries (Japan, India and Korea) have imposed mandates on taxicabs operating in certain cities.

[39] More detailed descriptions of the individual country experiences are included within a paper prepared for DOE: *Summary of Domestic and International Experience with Alternative Transportation Fuels* by David E. Gushee, R.F. Webb Corp.

Transition Scenarios and Necessary Measures

As discussed previously, DOE's main analysis of transition pathways, issues, and measures to achieve the 30 percent goal is being undertaken in conjunction with the development and use of the TAFV model. DOE has, however, reviewed other existing studies of possible transitions and policy measures. DOE has identified as the best and most pertinent of these a series of studies commissioned by the Congressional Research Service (CRS) in response to a request of the U.S. Alternative Fuels Council, published in April 1992. CRS commissioned five studies to identify the types of policy levers that would be necessary to cause the desired transitions to a marketplace where vehicles using five fuels would achieve market penetrations of 5 percent each, the costs of the various policies, and the rates at which the vehicles and fuels could be expected to appear.

The five fuels considered included methanol, ethanol, natural gas, LPG, and electricity. A broad array of policy levers was identified as necessary for each of the fuels to achieve the 5 percent goal. To provide adequate supply and retail availability, each fuel was believed to require subsidies/tax credits of over $3 billion except for LPG, which was believed to require $1 billion in subsidies to achieve 15,000 new stations. The 5 percent share for ethanol would be achieved through 10 percent blending in half of all U.S. gasoline, would require a mandate for such blending in addition to the existing tax exemptions, and additional investment tax credits. There would be no certainty that the 5 percent shares for the various fuels would be reached even with the levels of subsidies identified (representing costs incremental to conventional fuels), because total investment would be much greater than these amounts.

EPACT does not target market shares for particular fuels; nor does there appear to be any interest in the U.S. in setting such targets or in designing programs toward fuel-specific goals. Such was not necessarily the intent of the CRS study series. Rather, comparing and contrasting the relative hurdles faced by the different replacement fuels helps shed light on a number of issues which must be considered in conceptualizing, let alone designing, a coherent and effective approach to promoting transition to substantial replacement fuel use.

These studies all concluded that, under existing price relationships, public policy intervention would be necessary in order for alternative fuels to substantially penetrate the light-duty vehicle market. That intervention would have several dimensions:

- Subsidies to vehicle purchasers;
- Subsidies to fuel providers for infrastructure development;
- Subsidies to fuel purchasers; and
- Governmental support
    - Information programs,
    - Research and development, and
    - Technology transfer.

Mandates could, conceivably, serve as substitutes for subsidies; the CRS study used subsidies as a mechanism to estimate the amount of effort required to make the transition.

Table 2. Critical Path to 5 Percent Penetration for Each Fuel
(California Phase II gasoline is taken as the competitive reference point)

OBSTACLE	METHANOL (M85/M100)	ETHANOL (E10/E85)	NATURAL GAS (Dedicated)	PROPANE (Dedicated)	ELECTRIC
Fuel Cost	Without transitional subsidy, incremental methanol primarily from imports. 50 percent investment tax credit for investment in domestic methanol capacity (about $2 billion). Temporary subsidy of 15 to 30 cents per gallon seems needed (about $2 billion) for price reduction pending economies of scale. Subsequently self-sustaining.	Priced about 20 cents/gal. more than competitive octane sources. 25 percent investment tax credit suggested for new ethanol capacity; $2.5 billion. Over 10 years, $3 billion increased consumer fuel cost (fuel standard replaces blender tax credit). Subsequent cost path uncertain but promising.	Has price advantage of 30 to 45 cents/gal. at "city gate" (depends on distance of city from gas source). Price may rise slightly from additional demand but not enough to dissipate advantage.	Price advantage of 30 to 45 cents per gallon at "city gate." Price will rise some with added demand but not enough to dissipate advantage. Some investment tax credits probably necessary to induce increased domestic supplies.	Batteries cost a lot and have short lifetimes. Utility ownership and rate basing for several years, followed by subsidy declining year by year in percentage, suggested. About $24 billion involved, including costs of recharging (see below). Subsidy would be about $4 billion. Possibly self-sustaining thereafter.
Vehicle Cost	Currently $100-$300 for M85. For M100 currently around $2500 per vehicle, estimated to decline rapidly and perhaps disappear as production scale increases.	No change for E10. For E85, same as for M85.	Currently up to about $2500 per car higher. $800 to $1000 higher in volume production. Assistance in start-up costs or subsidy to vehicle buyer indicated.	Currently $800 to $1200 per car higher. Perhaps half that in volume production. Assistance in start-up costs or subsidy to vehicle buyer indicated.	EVs (less batteries) initially cost up to $10,000 more than gasoline vehicles, declining over time. Subsidies of 25 percent of the incremental cost would total about $3 billion over 10 years. Subsequently self-sustaining.
Fuel Transportation Cost	Two gallons needed per gallon gasoline replaced. About 5 percent expansion of system needed. Not viewed as a critical obstacle.	Refinery, pipeline, and/or terminal practice must be modified. About $3 billion investment needed, with investment tax credit of about $600 million suggested.	No change.	Tankage at terminals to be expanded.	Not expected to be critical except perhaps in some local situations.
Retail Distribution Cost	Service station receptivity an issue. Incremental cost ranges up to about $75,000. Assistance with low volume start-up indicated. About $1 billion, to support up to 25,000 service stations in affected areas at $40,000 each. Subsequently self-sustaining. Methanol federally taxed at gasoline Btu equivalency.	No Change. Ethanol currently has Federal tax waiver of 54 cents per gal. 5 percent target and investment tax credits would substitute for tax waiver.	Service station costs estimated at up to $300,000 more than gasoline for equivalent volume. Like methanol, will have start-up problems at low volumes. Would take about $4.5 billion for 15,000 stations. Currently not subject to highway tax.	Service station costs about the same as methanol, unless local safety rules add cost, but current practice includes high mark-ups except for fleet sales. Most existing outlets must be upgraded to become attractive to drivers. Currently taxed per gallon as gasoline (1.18 times Btu equivalency).	Recharging infrastructure must be developed. Subsidies included under Fuel Cost. Not subject to highway tax.
Research and Development	Formaldehyde emission catalysts.	Reduce ethanol production cost. About $230 million.	Onboard fuel storage.	Emission catalysts, onboard storage.	Batteries, motors, converters, control systems. Several billion dollars could easily be spent.

The results of the CRS study indicated that the different energy forms would require different kinds of policy prescriptions with differing costs, differing mixes of social, energy security, and environmental benefits, and differing rates of response. These conclusions are summarized in Table 2. Although some particulars of Table 2 regarding tax treatments and vehicle costs are out of date,[40] the conclusions are still indicative of the key policy issues that must be resolved and the energy and environmental effects to be expected from the various policy options. (Some vehicle costs have been updated from the original CRS table.)

The studies made clear the critical factors for each alternative fuel:

- For methanol, fuel price and infrastructure development are the big barriers; vehicles are priced the same or slightly more than the same models with gasoline power.

- For natural gas, whether compressed or liquefied, vehicle price and range and service station costs are the big barriers. Both are long-term problems.

- For propane, fuel price stability and fuel safety (fuel heavier than air) are the big barriers. Both appear to be resolvable.

- For ethanol, fuel price is an even bigger problem than it is for methanol. It was concluded that adding ethanol to gasoline would be a better path than making ethanol an alternative fuel.

- For electricity, vehicle price, range, and battery replacement cost are the big barriers. All appear to be long-term problems.

The studies showed that both propane and methanol appeared to be able to capitalize on temporary subsidies in the range of $10 billion each to become self-sustaining in the marketplace after 10 to 15 years. Whether the methanol and propane would be produced from domestic resources or imported would depend on favorable investment tax benefits during capacity expansion. Ethanol's future depends on technological developments to reduce costs of conversion of biomass to ethanol. Natural gas could become self-sustaining but would require more support ($25 to $30 billion) and a longer time frame than methanol or propane because the economic hurdles for both vehicles and retail fuel delivery are higher. The technical and economic hurdles faced by electric vehicles are the highest (more than $40 billion) of all the alternative fuels examined.

[40] EPACT introduced tax incentives for alternative fuel and electric vehicles and for construction of service stations, while the Omnibus Budget Reconciliation Act of 1993 modified fuel tax rates somewhat.

VI. ACTUAL AND POTENTIAL AVAILABILITY OF AFVs AND REPLACEMENT FUELS

Alternative fuel vehicle technologies are available for the principal alternative fuels believed most likely to play major roles in any transition to substantial alternative fuel use. Four vehicle models (a passenger car, a small pickup, and two minivans) are available to use ethanol fuel. Natural gas and LP gas vehicle technologies are sufficiently developed for such vehicles to be introduced into the market at high volumes if other factors, including cost, convenience, and infrastructure, were more favorable. Electric vehicle technology per se is also close to market-ready, but battery cost and range will probably constrain general market acceptance to favorable regions of the country between now and 2010.[41] Hybrid electric vehicles are currently being developed by the major auto manufacturers, but they are being designed initially to use conventional petroleum fuels and not alternative fuels. Fuel cell vehicles favor hydrogen or methanol, but much effort is being devoted to make conventional petroleum fuels acceptable for use. While hydrogen use in internal combustion engines has been demonstrated, it is likely that demand for hydrogen would come sooner from fuel cell vehicles. For these reasons, hybrid electric, fuel cell, and hydrogen vehicles will probably not play major roles in an alternative fuel transition, particularly in the period up to 2010.

A number of types of vehicles are currently available for purchase from original equipment manufacturers by the public and fleets, but not the whole range of vehicles in each of the alternative fuels. One mid-size passenger car is available for use with 85 percent ethanol/15 percent gasoline (E85) mixtures or any mixtures down to straight gasoline at nearly the same price as the same conventional model. One minivan is currently available for E85. A full-sized sedan is available for dedicated CNG operation and others may follow. Pickup trucks, vans, and minivans are available for dedicated CNG use. CNG vehicles (bi-fuel and dedicated) may also be obtained by conversions of conventional vehicles by many small conversion firms. Costs for dedicated CNG vehicles are generally $3,500 to $5,000 more than conventional models. Manufacturers are also providing bi-fuel CNG/gasoline or LP gas/gasoline light-duty vehicles as new vehicles and as vehicles specially configured for addition of CNG and LP gas fuel systems by aftermarket suppliers. Electric vehicles are currently available in subcompact passenger car and small pickup models, but at prices that are limiting their market primarily to the mandated zero emissions vehicle areas.

Most of the major alternative fuels are available at national and regional levels in volumes that are significantly greater than current transportation use. But only natural gas would currently be available from domestic sources in volumes corresponding to the section 502(b) goal of 30 percent replacement fuel use for 2010. LPG could be available in sufficient quantities to play a major role in a transition but a substantial amount (perhaps 40 percent) would be imported from outside North America to meet the 30 percent displacement goal. New methanol plant capacity would be needed for any substantial transportation fuel market. Under open market conditions without domestic investment incentives, much of the additional methanol to be used for vehicle fuel would probably be imported. Ethanol production from current crop resources could be

[41] The California Air Resources Board recently concluded that EV technology is not yet ready for general market acceptance and, accordingly, chose to postpone initiation of ZEV mandates from 1998 until 2003.

expanded significantly, but substantial alternative fuel use would have to be from cellulosic feedstocks and production processes that are currently under development. Taken together, the alternative fuels could be available as a transition proceeds with at least 50 percent being produced domestically.

None of the alternative fuels are currently available at retail for vehicle refueling in adequate networks to support widespread use. Adequate refueling sites could be available as the transition proceeds, but would involve additional capital costs.

Actual and Potential Availability of AFVs

The alternative fuel vehicles (AFVs) targeted by EPACT title V are light-duty vehicles represented by passenger cars, pickup trucks, and vans. The following sections discuss the present and near-term availability of AFVs that could be used to satisfy EPACT requirements. Medium-duty and heavy-duty vehicles are also available as AFVs, but are not included in this discussion.

Current AFV Technologies

The currently available AFV technologies can be grouped into five distinct categories:

- natural gas;
- LP gas;
- methanol;
- ethanol; and
- electricity.

Each of these are at different stages of technology development and explained in the following sections.

Natural Gas

Natural gas vehicle technology includes two distinctly different technologies — engine fuel metering technology and fuel storage technology.[42] Engine fuel metering technology has evolved to be essentially the same level as that of gasoline fuel systems, i.e., multipoint fuel injection, which facilitates good driveability and efficiency, and reduced emissions. Emissions of dedicated natural gas vehicles are the lowest of any internal combustion engine vehicles, meeting California's super ultra-low emission vehicle (SULEV) category. Detail improvements in natural gas fuel metering systems are likely in the future, though they are not necessary for natural gas AFVs to be competitive with conventional vehicles operating on gasoline or reformulated gasoline. Natural gas storage technology has made significant improvements over the last few

[42] Engine fuel metering technology includes the fuel system components that prepare and meter the fuel for use in the engine. Fuel storage technology includes the tank where the fuel is stored and associated equipment needed to move the fuel to the fuel metering system on the engine.

years resulting in lighter storage tanks for compressed natural gas (CNG). Research is ongoing to further improve CNG storage systems, though natural gas vehicles are viable with current technology storage systems. Natural gas can also be stored as a liquid (LNG) which improves its storage density, though the focus of LNG use for vehicles has been for heavy-duty vehicles and not the light-duty vehicles targeted by EPACT title V. While storage of natural gas as LNG on light-duty vehicles is possible, problems such as boil-off[43] have yet to be solved sufficiently for public use or for use in fleets typical of those that would be covered by EPACT programs.

While natural gas vehicle technology is evolving, it is currently at a level that should not deter prospective customers from purchasing natural gas vehicles. Of more importance is fuel availability and cost, and the initial cost of natural gas vehicles relative to conventional fuel vehicles. Also important is the development of a natural gas refueling infrastructure. The equipment to prepare CNG is expensive, and while natural gas refueling facilities are being established, achieving wide-scale coverage will take time and a large amount of investment.

Liquefied Petroleum Gas

Like natural gas, LPG vehicle technology includes both engine fuel metering and fuel storage technologies. LPG fuel storage technology is well-developed, and there appears to be little or no demand for improved storage technology, probably since storage pressures are typically in the range of only 120 to 200 pounds per square inch (psi). LPG fuel metering technology has focused on systems that can be added to existing gasoline fuel systems making the vehicle a bi-fuel vehicle. Because of this focus, these LPG fuel systems have not advanced to offer the same level of vehicle performance, driveability, and emissions capabilities that current gasoline or natural gas multipoint fuel injection systems offer. However, the overall performance of current LPG fuel systems should not impede the use of LPG as an alternative fuel. The vast majority of LPG vehicles now on the road are bi-fuel, converted from gasoline vehicles; the very limited numbers of LPG vehicles sold by auto manufacturers to date have all been dedicated. Regardless of the type of fuel system, LPG vehicles have demonstrated the capability to have low emissions with driveability and performance comparable to conventional gasoline vehicles.

LPG vehicle technology is relatively mature and should not deter prospective customers from purchasing LPG vehicles. It is likely that prospective LPG customers will base their purchase decisions primarily on issues such as fuel availability, range, vehicle and fuel prices, vehicle warranties, and resale value rather than their perception of the relative development of LPG vehicle technology.

[43] LNG storage tanks must be highly insulated to keep the LNG at cryogenic temperatures. However, even the best tanks eventually allow enough heat transfer so that natural gas must be vented to prevent pressure build-up that would damage the tank. The natural gas that is vented from LNG tanks is referred to as “boil-off.”

Methanol

The current technology for using methanol (M85[44]) is largely the same as used for gasoline vehicles. The only significant difference is that some of the fuel system components are made of materials compatible with methanol. Current methanol vehicles include a sensor that measures the percent methanol in the fuel, allowing compensation for mixtures of methanol and gasoline. This sensor allows either methanol or gasoline to be used as fuel, in the same tank. Vehicles with this capability are generically referred to as "flexible fuel vehicles" or FFVs. FFVs have the same performance and driveability as conventional vehicles, with emission levels that are the same as or better than their gasoline-only counterparts. Without the constraint of having to be able to operate using gasoline, methanol vehicles could be further optimized to improve efficiency, power, and emissions. However, present FFV technology is completely adequate for consumers to use methanol fuel, with the only drawback being reduced operating range compared to using gasoline.[45] The low incremental cost of FFVs relative to other alternative fuel vehicles is an additional incentive for their use. Methanol vehicle technology is mature and adequate to meet consumer needs as an alternative fuel vehicle.

While methanol can be stored and dispensed using essentially the same components as for gasoline (with materials changes), it is currently not widely distributed in large quantities. However, under certain conditions, service stations can upgrade existing tanks and dispensers for methanol. It is readily transported via truck or railcar to almost anywhere in the U.S. Currently, methanol is available through only a very sparse network of stations, which would have to be expanded greatly to support large numbers of methanol vehicles.

Ethanol

FFVs have also been designed for ethanol fuel, and in 1999 the production of ethanol FFVs are estimated to far surpass that of methanol FFVs. The only differences between ethanol and methanol FFVs are minor changes in materials and programming of the engine/fuel system computer. One benefit of ethanol vehicles is that their range is better than methanol vehicles (but still less than operating on gasoline). Ethanol faces the same fuel storage and dispensing hurdles as methanol, though not to the same extent.

Electricity

Electric vehicles (EVs) represent a radical change in vehicle technology. EVs are commercially available only in very limited numbers. Much intense development is currently ongoing on EV batteries, motors, drivetrains, and vehicle structures. Several auto manufacturers began offering

---

[44] M85 is a mixture of 85 volume percent methanol and 15 volume percent gasoline. The gasoline is required for cold-start capability in current technology vehicles and also provides flame luminosity benefits important to fuel use safety.

[45] Methanol fuel has only about 60 percent of the energy per gallon as gasoline—however, efficiency gains in use of about 10 percent are typical and some manufacturers have been able to increase the fuel tank size on their FFVs by 10 to 15 percent, resulting in a net range loss of 20 to 30 percent relative to gasoline-only vehicles.

EVs during 1997 and 1998, though their price is high and their geographic distribution limited, factors which have thus far discouraged high sales.

One advantage to EVs is that the electric grid is ubiquitous; EVs can be recharged from households if enough time is available for recharging (as much as 8 to 16 hours). However, for EVs to become widely accepted, fast-charge recharging facilities will need to be established at public locations in addition to slow charging facilities at personal residences or the locations where EVs are parked overnight. Fast rechargers are being developed but there is uncertainty as to how expensive such units might be in large production quantities and the effect of fast charging on battery durability.

Potentially Available Technologies

There are several AFV technologies that are in the research and development phase of development that may be available in the future. Of these, the most promising are hybrid electric and fuel cell vehicles, while hydrogen vehicles are also noteworthy.

Hybrid Electric Vehicles

Hybrid vehicles are vehicles with batteries and electric motor drives (which make their drivetrains similar to electric vehicles) and auxiliary combustion engines to recharge the batteries and/or provide power to the drivetrain. By not being limited to the range available with batteries, hybrids are envisioned to be much more appealing to the public. Hybrids also provide advantages to infrastructure development relative to electric vehicles because they will likely be designed initially to use gasoline. Hybrids require fewer batteries than pure EVs, which reduces vehicle cost. The engine could be designed to operate on alternative fuels rather than gasoline.

Series configuration hybrid electric vehicles use only electrical power for the drive. The battery power source is supplemented with additional electrical energy provided by an engine-driven generator. The engine would be used for high power demands such as acceleration and hill climbing, or when a certain level of battery discharge is detected.

Parallel configuration hybrid electric vehicles, by contrast, supplement the battery-electric motor system with a combustion engine that is mechanically connected to the drive wheels. In this configuration, the battery provides the high energy needs of the vehicle (such as for acceleration and moderate speed driving conditions), while the engine satisfies the high power demand function (e.g., for extended acceleration and highway driving conditions), and simultaneously recharges the batteries.

Toyota has been selling a hybrid vehicle, the Prius, in Japan[46] since 1997. Testing of this vehicle by the EPA has shown that it has emissions that are substantially lower than current regulations, and has the potential to meet the rigorous LEV-II standards being proposed by California. This

[46] *Evaluation of a Toyota Prius Hybrid System (THS)*, August 1998, U.S. Environmental Protection Agency, EPA 420-R-98-006.

vehicle also demonstrated excellent fuel economy, especially in urban driving. Toyota has announced that it will sell the Prius in the U.S. starting in mid-2000. Honda has beat Toyota in the market with their hybrid 2-seat passenger car called "Insight." The Insight has City and Highway fuel economy ratings of 61 and 70 mpg, respectively. Honda plans to sell 5,000 Insights in the U.S. per year. The Prius is a series hybrid while the Insight is a parallel hybrid.

Fuel Cell Vehicles

Fuel cells are electrochemical devices that convert the chemical energy of a fuel and an oxidant directly into electrical energy (without combustion). Fuel cell vehicles have the potential to be two to three times more efficient than today's vehicles. While fuel cell vehicles operating on hydrogen are zero emission vehicles (ZEVs), emissions from fuel cell vehicles operating on conventional and alternative fuels are expected to be well below the current Federal and California standards. They differ from batteries in that they will continue to provide electricity as long as the fuel and oxidant are fed to them. Fuel cell vehicles are essentially electric vehicles with reduced battery storage and addition of a fuel cell. The primary advantage of fuel cell vehicles over electric vehicles is that fuel cell vehicle range is only constrained by the amount of fuel carried onboard. However, fuel cells are not yet developed sufficiently to be used in vehicles. The introduction of electric or hybrid vehicles should nicely pave the way for fuel cell vehicles when they are commercially ready.

The fuel of choice for fuel cells is hydrogen. Because hydrogen fuel infrastructure is not well developed, an onboard fuel processor may be used initially that would reform gasoline, ethanol, methanol, or natural gas to hydrogen for fuel cell use. (Prototype processors have been developed and demonstrated in DOE's fuel cell RD&D program.) Although onboard reformation adds significant complexity to the fuel cell system, it has the advantage of using the existing gasoline infrastructure and developing alternative fuel infrastructures. Therefore, fuel cell vehicles using gasoline, ethanol, methanol, and/or natural gas could contribute to EPACT goals by early in the next century. Fuel cell vehicles using stored hydrogen onboard the vehicle may be too far in the future to contribute to the 2010 EPACT goal.

Hydrogen Vehicles

Hydrogen is a very good fuel for transportation vehicles because it can be made from non-fossil sources and its only combustion product is water vapor when used in fuel cells or water vapor and modest amounts of oxides of nitrogen when used in internal combustion engines. The major drawback to using hydrogen as a fuel is that it is very difficult to get enough onboard for a practical operating range. Until the energy storage density of hydrogen is improved significantly, it is not likely to be considered a practical transportation fuel.

Another major hurdle facing hydrogen vehicles is large-scale hydrogen production and distribution. It has been demonstrated that hydrogen can be distributed using much the same technology as for natural gas, but establishing hydrogen pipeline distribution networks would take a significant period of time and represents a large capital investment. Hydrogen could also be produced by a distributed grid of small reformers at the service station level using the existing

natural gas distribution system. However, this option is also capital intensive. Perceived safety issues would also have to be addressed.

Availability by Vehicle Type

U.S. automakers are offering a variety of passenger cars for use with compressed natural gas (CNG) and ethanol (E85). Light-duty trucks and vans are offered with CNG fuel systems, both bi-fuel and dedicated. Electric light-duty cars and trucks are currently being offered. Light-duty trucks and vans are being offered with bi-fuel propane fuel systems. In the past, Ford has offered a dedicated medium-duty truck with propane power, though it is not currently being offered. General Motors (GM) offers a medium-duty truck with propane power.

New AFV Passenger Cars

Until recently, the auto manufacturers focused on M85 flexible fuel vehicles (FFVs) for passenger cars. Ford offered M85 FFV Crown Victorias in 1989, switching to its Taurus model in 1991. Ford offered M85 Taurus FFVs from 1991 through the 1998 model year. GM offered an M85 Lumina FFV in 1991 and 1993, but not since then. Dodge offered M85 Spirit FFVs in 1992 through 1994, and offered an M85 Intrepid FFV in 1995. Dodge does not currently offer any M85 FFVs.

M85 FFVs paved the way for similar E85 models. Ford has offered an E85 Taurus FFV since 1993 and continues to offer this model today. GM offered an E85 Lumina FFV in 1992 and 1993.

Ford began offering a dedicated CNG version of its Crown Victoria in 1996 and continues to offer it. Ford began producing a bi-fuel CNG version of its Contour in 1997, and this model is still available for the 1999 model year. GM offers a bi-fuel CNG Chevrolet Cavalier sedan, which it began selling in 1998. Honda began offering a CNG version of its Civic (the Civic GX) in 1998. The Civic GX is being produced on the same assembly lines in East Liberty, Ohio, as regular gasoline Civics.

The development of electric vehicles (EVs) has lagged other AFVs because of high vehicle and battery costs and limited operating range. GM has been leasing the EV1 in southern California, Phoenix, and Tucson, based on a value in the range of $30,000 to $35,000. GM believes that the market for the EV1 is for use as a second or third vehicle in up-scale, non-fleet applications. To date, GM has leased 578 EV1s. Honda began offering a subcompact passenger car EV (the EV Plus) late in the 1997 model year, also predominantly in warm-weather climates. Honda leased 267 EV Plus's to date and has announced that they are not leasing any more EVs for now. Nissan leased 30 Altra EVs during the 1998 model year as a test. Toyota offers an EV version of its popular RAV4 sport utility vehicle to fleets only, at a price of $42,000, or as a lease. To date, Toyota has sold or leased 507 RAV4-EVs.

New AFV Light Trucks and Vans

Unlike passenger cars, auto manufacturer interest in AFV light-duty trucks and vans has focused on CNG. Ford has produced some M85 FFV vans for test and demonstration, but it has not indicated that they will be made available as production units in the future.

Some interest has been recently shown in using alcohol fuels in light-duty trucks. Chrysler began offering E85 FFV minivans in 1998. This was done by including flexible-fuel components in all of the minivans with the 3.3 liter V-6 engine. Chrysler projects that production of the FFV minivan could reach 200,000 units in 1998. In August 1998, Ford began offering its 1999 Ranger pickup with a 3.0-liter ethanol flexible fuel engine. Its price is the same as the conventional gasoline-powered pickups. During November 1998, Ford announced that the U.S. Postal Service had placed an order for 10,000 ethanol-powered vehicles, which would make this the largest ethanol-powered fleet anywhere.

Ford offered pickups and vans in dedicated CNG configuration in 1998. In addition, Ford has developed a program to certify dealerships and other companies to produce dedicated and bi-fuel natural gas and LPG pickups and vans. Ford will sell nearly completed vehicles to these qualified companies who would add their own natural gas or LPG fuel systems. The engines in these vehicles have modifications to make them more durable and better suited to gaseous fuel operation. Ford offers the warranty on the basic vehicle and the converter offer the warranty on the fuel system. Ford calls this the qualified vehicle modifier (QVM) program. In 1999, Ford offered a natural-gas version of its full-size Expedition sport utility vehicle.

GM produced 2,600 dedicated CNG pickup trucks since 1992, but stopped offering them for a period of time because of CNG cylinder failures in two vehicles where the CNG cylinders were exposed to battery acid from old batteries carried in the truck beds. Beginning in 1998, GM resumed the sales of CNG bi-fuel pickups.

Chrysler started offering a dedicated CNG version of its full-size van in 1992. In 1994, it added dedicated CNG minivans. However, in 1996 Chrysler announced that it would suspend CNG vehicle sales until demand increases beyond 1996 levels (less than 800 units). By the 1999 model year, however, Chrysler had returned to the CNG market with dedicated CNG full-size passenger and cargo vans.

Ford, Chrysler, and GM have all developed electric versions of selected vans. The Ford van, called Ecostar, is based on a small European Ford vehicle. The Ecostar was tested by several utilities, but it was not made generally available for sale. Ford started offering an electric version of the Ranger compact pickup in the 1996 model year through a conversion company that adds the electric vehicle components. In 1998, Ford began offering the electric Ranger as a new Ford vehicle without going through a vehicle converter. The electric Ranger continues to be offered in 1999, with nickel metal hydride batteries as a new option for California purchasers. The GM EV van, called the G-Van, is a full-size van that was also tested by utilities, but was also not available for sale. Chrysler offered an electric version of its minivan to electric utility fleet

Table 3. History of AFV Vehicle Model Availability

Year	CNG Pass. Car	CNG Light Truck	M85 Pass. Car	M85 Light Truck	LPG Truck	E85 Pass. Car	E85 Light Truck	EV Pass. Car	EV Light Truck
1989			Ford Crown Victoria		Ford F600/F700				
1990					Ford F600/F700				
1991			Ford Taurus Chev. Lumina		Ford F600/F700				
1992		Dodge Vans Chev. PU[1] Trucks	Dodge Spirit	Ford Vans	Ford F600/F700	Chev. Lumina			
1993		Dodge Vans	Ford Taurus Chev. Lumina Dodge Spirit		Ford F600/F700	Chev. Lumina Ford Taurus			Chrysler TEVan Minivan
1994		Dodge FS[2] Vans Dodge Minivans	Ford Taurus Dodge Spirit		Ford F600/F700	Ford Taurus			Chrysler TEVan Minivan
1995		Dodge FS Vans Dodge Minivans Ford Bifuel PUs Ford Bifuel Vans	Ford Taurus Dodge Intrepid		Ford F600/F700	Ford Taurus			Chrysler TEVan Minivan
1996	Ford Crown Victoria	Dodge FS Vans Dodge Minivans Ford Bifuel PUs Ford Bifuel Vans	Ford Taurus		Ford F600/F700 Ford Bifuel Pickup	Ford Taurus			Ford Ranger
1997	Ford Crown Victoria Ford Bifuel Contour	Ford Pickups Ford Vans	Ford Taurus		Ford F700	Ford Taurus		GM EV1	Ford Ranger
1998	Chevrolet Bifuel Cavalier Ford Crown Victoria Ford Bifuel Contour Honda Civic	Ford Pickups Ford Bifuel PUs Ford Vans Ford Bifuel Vans GM FS Bifuel PUs	Ford Taurus		Ford Bifuel Pickup Ford Bifuel Van GMC Medium-Duty Truck	Ford Taurus	Chrysler Minivan	GM EV1 Honda EV	Ford Ranger GM S-10
1999	Chevrolet Bifuel Cavalier Ford Crown Victoria Ford Bifuel Contour Honda Civic	Dodge FS Vans Ford Pickups Ford Vans Ford Bifuel Vans Ford Expedition			Ford Bifuel Pickup GMC Medium-Duty Truck	Ford Taurus	Chrysler Minivan Ford Ranger Special Ford Vehicle for USPS	GM EV1 Honda EV	Chrysler Minivan Ford Ranger GM S-10 Toyota RAV4

[1]Pickup [2]Full-size

customers between 1993 and 1995, and 58 were sold. For 1999, the Chrysler EPIC (Electric Powered Intraurban Commuter) minivan will be available for lease to fleet owners in New York and California based on a list price of around $39,000. Chrysler plans to produce around 2,000 of these vans on the same production line as the regular gasoline minivans.

Table 3 presents the AFVs offered for sale by the auto manufacturers to date and their plans for offering AFVs in the near future. Table 3 illustrates that the number of AFV models has expanded over the years to include a wider range of manufacturers and fuel types. Those fleets that must comply with EPACT should find choices available among vehicle types, alternative fuels, and manufacturers. (Table 3 does not show the AFVs built before 1989, which were mostly research and development or demonstration vehicles, such as the 600 methanol Escorts built by Ford for the California Energy Commission. The only AFVs previously commercially available from OEMs in the U.S. were the propane passenger cars offered by Ford in 1982-84 of which only a few hundred were sold.)

Converted Vehicles

There are many aftermarket vehicle converters throughout the U.S. that install natural gas and LPG fuel systems on conventional fuel vehicles. Almost any light-duty vehicle can be converted to run on natural gas or LPG, though most favor bi-fuel operation because it is difficult to install sufficient gaseous fuel storage capacity without compromising cargo carrying space or load carrying capacity. New models, however, are becoming increasingly more difficult to convert because of the complexity of fuel and emissions control systems.

There are also a few dozen companies that convert conventional fuel vehicles to electric operation. Vehicles converted to EVs have the economic disadvantage of having to remove the conventional fuel power train and replace it with an EV power train. Vehicles converted to EVs tend to have limited operating range and compromised load carrying capacity because of the weight of the batteries required.

With regard to potential or long-term availability of AFVs, automobile OEMs have always held that they would produce AFVs in sufficient volumes and models to satisfy demand as long as demand is adequate to justify production runs.

Actual and Potential Availability of Replacement Fuels

National Availability

Currently, total production of all of the major alternative fuels (natural gas, LPG, methanol, ethanol, and electricity) far exceeds the volumes of the fuels utilized as alternative transportation fuels. All of these fuels have other uses both within and without the transportation sector. In some cases, these other uses would limit the availability of the existing production capacity for high volume use in AFVs.

Throughout much of 1994, methanol was in short supply both in the U.S. and in world markets because of rapid growth of demand for it in production of methyl tertiary butyl ether (MTBE), demand for which has grown dramatically due to oxygenated fuel and reformulated gasoline requirements of the Clean Air Act Amendments of 1990, and because of unanticipated temporary loss of some production capacity. Because of this, from the middle of 1994 through early 1995, methanol prices considerably exceeded any level that would make methanol use in AFVs competitive with gasoline. The 1994 prices were also far above costs of production, however, and are not an indication of long-term prices. U.S. and global supplies of natural gas, the preferred feedstock necessary for production of methanol, are abundant. Methanol production technology is well-developed and plant construction is available from any number of providers. There are no fundamental constraints to methanol production capacity rising to keep pace with any demand that might be generated by alternative fuel use. World class methanol plants, however, are very large and require enormous capital investment. (Historically, world class plants have been in the range of 1,000-2,500 tons-per-day. Today's designs for low cost production facilities are often in the 5,000 ton-per-day range and by 2010 technologies for 10,000 ton per day plants are expected.[47]) Investment and supply are, therefore, considered "lumpy." Finance sources are reluctant to commit to investment on such scale merely in anticipation of uncertain new demand.

Technical Report Fourteen forecasts prices for alternative fuels as well as conventional and reformulated gasoline in 2010 under various scenarios relating to tax treatment, regulatory constraints, ethylene demand, and domestic and international supplies of natural gas. Methanol is forecast to be priced competitively with conventional gasoline on an energy equivalent basis, although in some scenarios it is priced slightly higher and fails to provide the margin of price advantage that might be necessary to overcome consumer uncertainty and inconvenience factors. Methanol prices were lower than reformulated gasoline prices on an energy equivalent basis in all but a few scenarios.

Liquefied petroleum gas is also available in sufficient quantities to supply the transportation market for the foreseeable future, at least up to LPG's market share in *Technical Report Fourteen*'s scenarios (10 to 15 percent under most scenarios). Reformulated gasoline and other EPA fuel volatility regulations result in substantial reductions in blending of butanes and other LPG in U.S. gasoline, which could be turned to use in AFVs (though most LPG vehicles in the U.S. are currently designed to run only on propane). LPG prices have historically fluctuated from substantially less to slightly more than gasoline on an energy equivalent basis, which makes LPG quite viable given that the incremental vehicle cost can be as low as $400, if adequate vehicle production volumes are realized. *Technical Report Fourteen* shows LPG costing less than both reformulated and conventional gasoline on an energy equivalent basis in all of the market scenarios for the year 2010.

---

[47] Each 5,000 ton per day plant would represent supply for approximately 600,000 light-duty vehicles in normal use.

Availability of domestically sourced methanol and LPG is a different matter. Under *Technical Report Fourteen*'s market simulations, virtually all of the incremental methanol supply to the U.S. for transportation use would be imported. It displaces petroleum imports on a one-for-one energy equivalent basis, meaning that there are no secondary effects that result in additional petroleum imports. About 40 percent of the incremental LPG for AFV use would be imported from outside North America, of which about half would come from petroleum refineries and half from gas processing. However, much of the domestically produced propane to be used in AFVs would be diverted from other uses. This would create additional demand for other fuel sources to fill the vacuums, which would be met largely by petroleum imports, offsetting much of the reduction in transportation demand.[48]

Natural gas abounds in the U.S. far beyond the volumes that would be utilized in the transportation sector under the EPACT goals. The pipeline price of natural gas is below that of gasoline, but the infrastructure to deliver it as CNG to vehicles is more costly than the comparable gasoline infrastructure. In addition, the operating costs to compress natural gas to CNG pressures typically adds about $0.10 to each gallon equivalent of CNG. Typical retail prices of CNG, however, are below those of gasoline. CNG is also taxed at a lower rate at the Federal level (5.6 vs. 18.4 cents per gallon) and many States have reduced tax rates for CNG as well.

Electricity to recharge EVs is in plentiful supply if off-peak power is utilized. Using off-peak power, the per-mile cost of electricity to power EVs is considerably less than the gasoline cost of operating gasoline vehicles. However, when the cost of chargers and replacements of current technology batteries are taken into account, the per-mile operating cost of EVs is now typically higher than the cost of gasoline for gasoline vehicles.

Oxygenates (alcohols and ethers blended into conventional fuels) are also classified as replacement fuels under EPACT. Although there were predictions of oxygenate shortages to attend the initiation of the EPA reformulated gasoline program in December 1994-January 1995, no substantial shortages did, in fact, occur.

---

[48] EPACT defines energy imports as supplies from outside of the North American Free Trade Agreement (NAFTA) countries, as reflected in *Technical Report Fourteen's* estimates of imports. The study does not break out the specific country sources of import supply outside North America. For example, the import share of the Persian Gulf countries is not determined.

Regional Availability[49] [50]

Methanol is not expected to be distributed in petroleum pipelines, but distributed from methanol plants and marine terminals by tanker truck and railcar. Since gasoline is currently distributed by truck within ranges of 100 miles, distribution of methanol should be competitive within 100 mile radiuses of production facilities and marine terminals. Of the 50 largest metropolitan areas in the U.S., 31 have marine terminals and 11 others are within a 100 mile range of a marine terminal. These areas contain most of the population of the U.S. and over 75 percent of vehicle miles traveled in the U.S.

An existing network of natural gas distribution pipelines serves all States in the U.S. except for Alaska, Hawaii, and Vermont. (Vermont is connected to Canadian pipelines.) Local utilities operate low pressure distribution networks around cities, towns, and surrounding regions. All major population centers in the 48 States with transmission lines have natural gas service and some 51.5 million households and firms have such service. While some excess capacity exists in the national grid, the additional loads may require expanding some interstate transmission pipelines for peak loads, including rerouting of flows, addition of compressors, looping of the lines at strategic bottlenecks, and some strategic storage capacity. No new regional transmission lines are expected to be required even for displacement of one million barrels per day equivalent. Adding new areas that previously had no access, however, will require distribution lines and connections to transmission lines, both of which are costly. The most significant constraint will be providing availability to remote stations along interstate highways, most of which are outside distribution networks and will require dedicated pipelines. DOE has estimated the cost for such dedicated pipelines to be $200,000 per mile. For the scenario to displace one million barrels of oil per day, the total cost of dedicated pipelines was estimated to be over $1 billion. Costs of all the other upgrades to gas transmission and distribution networks to serve regular stations was estimated at $604 million.

The existing LPG network includes 860 natural gas plants and 190 refineries that produce LPG, over 70,000 miles of cross-country pipelines (13 major pipelines with capacity of over 20 billion gallons per year), 12,700 railway tank cars, 60 barges and tankers, 26,000 transport and delivery trucks, 9,000 storage and distribution terminals, 16 import terminals, and 16 billion gallons of underground storage capacity. The pipeline network provides low cost transportation to terminals in 25 States. Expansion of the system to accommodate a substantial increase in LPG volume for transportation purposes would require significant investments in storage and

---

[49] This text is drawn substantially from *Assessment of Costs and Benefits of Flexible and Alternative Fuel Use in the U.S. Transportation Sector*, Technical Report Four: Vehicle and Fuel Distribution Requirements, August 1990, U.S. DOE Office of Policy, Planning and Analysis, DOE/PE 0095P except where otherwise noted.

[50] Infrastructure cost estimates are provided as indications of the potential availability of the alternative fuels. The studies drawn on did not estimate any savings from additional transmission and distribution infrastructure for expanded volumes of petroleum products, which might otherwise be required. DOE is not aware of any existing studies which investigated the potential for such savings.

distribution infrastructure in addition to any expansion of the network to other regions, such as California and other Western States.[51] DOE had a contractor perform an assessment of LPG infrastructure for motor vehicle use in 1992.[52] The study estimated the infrastructure necessary for use of 13.7 billion gallons of LPG per year (10.05 billion gallons gasoline equivalent per year or 655,300 barrels per day gasoline equivalent) by light-, medium-, and heavy-duty vehicles. It estimated the costs for additional transportation and storage capacity at $2.43 billion to $2.51 billion. *Technical Report Fourteen* included both scenarios with less LPG use than the 1992 report's 655,300 barrels per day equivalent and scenarios with greater LPG use, but all of the scenarios that resulted in high fuel displacement by replacement fuels included higher LPG use. The scenario that projected exactly 30 percent replacement fuel use in 2010, for example, showed 866,000 barrels per day gasoline equivalent LPG use. Scaling the cost estimates from the 1992 study up proportionately to the increased volume of the 30 percent replacement fuel use scenario would give LPG distribution cost estimates of $3.21 billion to $3.31 billion.

It is not anticipated that any significant expansions to electrical transmission or distribution infrastructure would be required even if substantial numbers of electric vehicles were to be used in the U.S. Several million electric vehicles in daily use (up to 5 percent of total light-duty vehicles) would only be expected to increase electricity needs by less than one percent.[53] Most recharging of vehicles would probably occur at night, during off-peak power usage and generation intervals. [54]

Availability of Refueling Sites

The potential availability of alternative fuel refueling infrastructure is dependent on numerous technical and economic variables. All the alternative fuels being considered in this report can be distributed and retailed nationally without any constraints due to the need for development of new technology. However, the cost of providing the refueling infrastructure varies widely among the alternative fuels. For instance, M85 infrastructure costs are relatively small since much of the existing conventional liquid fuel infrastructure can be used. On the other hand, the infrastructure cost for CNG is high because of the high cost of compression equipment. For electricity, costs

---

[51] *Investigation Regarding Federal Policy Actions for Encouraging Use of Liquefied Petroleum Gas as a Motor Vehicle Fuel*, April 1992, prepared by R.F. Webb Corporation for Congressional Research Service.

[52] *Assessment of LPG Infrastructure for Transportation Use*, Final Report, September 1992, prepared by EA Energy Technologies Group for Oak Ridge National Laboratory.

[53] *Electric Vehicle Policy Perspectives and Pathways to the Year 2010*, April 1992, prepared by EA Engineering, Science and Technology for Congressional Research Service, p. 4.

[54] Experience with GM's EV-1 program indicates that, currently, EV motorists are strongly inclined to top off batteries whenever they return home, at least during their early experience with EVs. If electric rate differentials are substantial enough, however, electric motorists should adjust over time to their actual needed recharging while taking advantage of the lower night rates to the extent possible.

are high because of the need for one charger per EV, unless fast-recharging times similar to conventional fuel refueling become viable.

But infrastructure cost alone will not determine which alternative fuels will become available at retail service stations. Prerequisite to private investment is a high probability of adequate return to justify the risk. Alternative fuel infrastructure development is likely to follow preferences for alternative fuel vehicles (as expressed in the market) and the cost of the fuel for those vehicles. While the cost of alternative fuel infrastructure to the consumer can be accounted for in the retail price of the fuel, vehicle performance and convenience factors such as the time for refueling and operating range will be major factors determining the alternative fuel or fuels most preferred. It is possible that one or more alternative fuels may become available on a national basis, and that certain regions of the country may have different concentrations of distribution and retailing infrastructure for one (or more) alternative fuel(s) relative to other regions.

As above for regional availability, refueling infrastructure cost estimates are shown below as factors of the potential availability of refueling sites. All of the previously cited studies assumed that the alternative fuel would displace one-third of the gasoline dispensed at existing stations, reducing the stations' gasoline capacity proportionately. In many of the key urban areas, limited queuing space would likely dictate such a substitution, while, in other cases, the alternative fuel capability could be incremental to the existing facility or could be at a new (possibly separate) facility altogether. In any event, overall fuel demand is not expected to grow between now and 2010 at a rate that would approach the (alternative fuel) refueling capacity which would be added if the EPACT 30 percent goal were to be met, so that some existing capacity would be made redundant. The impact of substantial alternative fuel capacity on existing station fuel capacity has not yet been adequately assessed, making it problematic to adequately incrementalize the infrastructure costs by netting out other cost savings.

Methanol/Ethanol Stations

DOE's Alternative Fuels Data Center identified 91 methanol refueling sites and 74 ethanol refueling sites in operation in the U.S. in 1998 (see Figure 16). Sixty-six of the methanol stations are in the State of California and most are retail service stations available to the general public while only a very few are exclusively central refueling sites for fleet vehicles. The New York State Thruway Authority operates nine methanol refueling sites across New York along the New York Thruway for its 45 methanol vehicles. The States of Arizona, California, Colorado, Illinois, Georgia, Maryland, Michigan, New York, Tennessee, and Washington each have at least one or more methanol refueling stations offering unrestricted public access. The ethanol sites are virtually all in Midwestern States.

In a 1990 Technical Report, DOE's Office of Policy, Planning and Analysis estimated the number of refueling stations necessary to deliver 2.4 million barrels per day of M85 to motorists using a formula based on assumed size of service stations and an average volume of each fuel dispensed per station, assuming that M85 would be dispensed along with two grades of gasoline

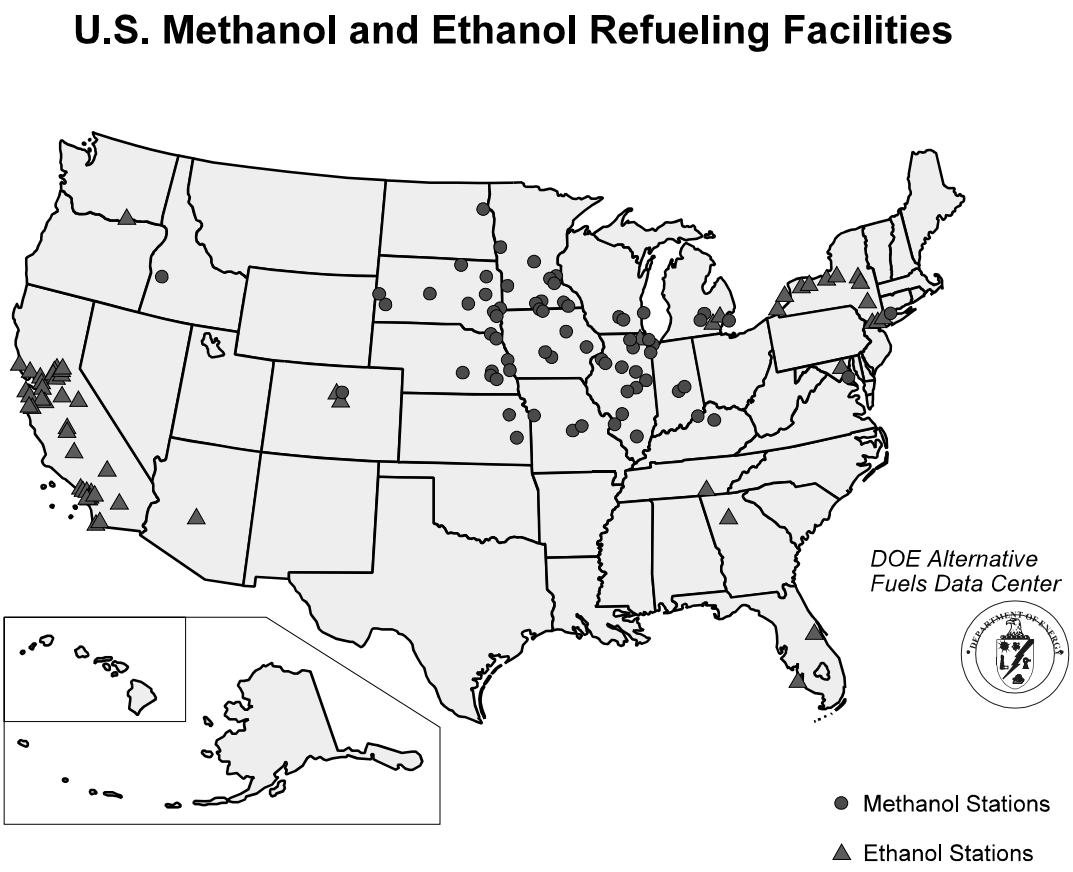


Figure 16. Methanol and Ethanol Refueling Facilities in 1998

in roughly equal proportions.[55] (The calculations could also be applied to E85 or to some combination of M85 and E85 stations.) This analysis resulted in an estimate of 91,000 required refueling stations or roughly half of all stations in the U.S. to dispense M85. This volume of M85 is considerably greater than that projected by any of the scenarios of *Technical Report Fourteen* and other studies; however, the percentage of stations is also greater than other estimates of what would be required. Under *Technical Report Fourteen*'s 30 percent replacement fuel use scenario with equal tax treatment, 774,000 gasoline equivalent barrels per day of M85 are projected to be used, which represents 1.35 million barrels of M85 per day. Using the same volume per station as in the 1990 DOE study, approximately 51,500 stations would be required. This is also more consistent with the 1992 Congressional Research Service study, which found that approximately 25 percent of stations would have to carry methanol in order to win customer acceptance, citing marketing studies by Ford.[56] The 51,500 stations would

[55] *Assessment of Costs and Benefits*, Technical Report Four, *DOE- OPPA, supra*, p. 23.

[56] *Federal Policy Actions for Encouraging Methanol Use*, April 24, 1992, prepared by Acurex Environmental Corporation for Congressional Research Service.

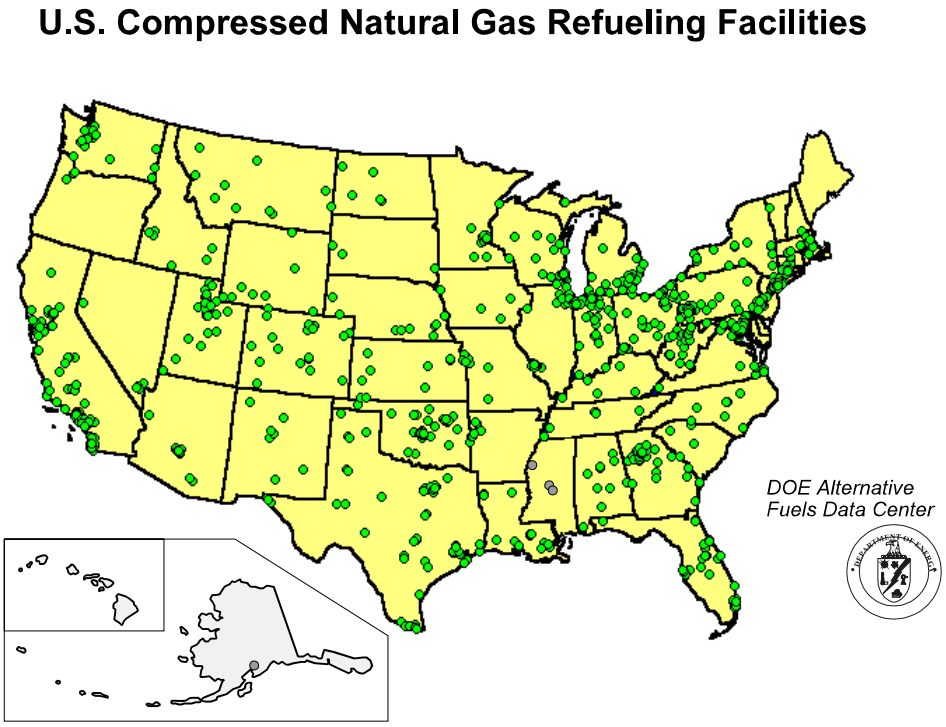


Figure 17. CNG Refueling Facilities in 1998

be more than 25 percent of all stations in the U.S. and would be considerably more than 25 percent of the stations in the regions of methanol AFV penetration.

The cost of making each station compatible with methanol was estimated by the DOE 1990 Technical Report as $45,000 if an existing system was removed at each station installing the M85 capability. If methanol compatible tanks were instead installed during the course of normal renovation or replacement or in response to regulatory requirements, the cost could be much lower, possibly as low as $5,000. (Many of the tanks being installed as replacements today are already methanol compatible.) The total station cost if all of the 51,500 stations incurred the full $45,000 cost would be approximately $2.3 billion dollars. If 25 percent of these stations installed methanol capacity when they would otherwise be replacing tanks, the total cost would be approximately $1.8 billion.

CNG Stations

In 1998, there were 1,279 CNG stations established across the U.S. (see Figure 17). Of these, just over half offer open access for CNG sale to the public or sell CNG to the public by arrangement.[57]

[57] Data from DOE's Alternative Fuel Data Center (http://www.afdc.doe.gov).

There are two basic types of CNG refueling stations: time-fill and fast-fill. The time-fill system uses a lower powered compressor and little or no storage capacity and would typically be used for overnight refueling at fleet facilities (or private homes). The fast-fill system includes storage of a substantial volume of natural gas already compressed as well as a more powerful compressor and can refuel vehicles in approximately eight minutes.

The 1990 Technical Report (*supra* fn. 9) made cost projections based on typical station capacities and designs for both regular public stations and truck stops. The regular public refueling stations were designed to handle an average of 300 vehicles per day with four nozzles, fueling each within eight minutes, with a peak capacity of 30 per hour in two 2-hour continuous peak demand periods. The average cost for installing CNG capacity at these stations was estimated at $320,000, which does not include any distribution cost for constructing pipelines to stations not in areas otherwise served by natural gas. The per vehicle cost for this station installation based on the capacity was estimated at $177 for the public stations.

The Technical Report estimated requirements for dispensing CNG to displace one million barrels per day (bpd) of gasoline, including both the regular public stations and truck stops for refueling medium- and heavy-duty vehicles. The regular public stations accounted for approximately 675,000 bpd equivalent of this, dispensing 42.3 bpd at each of 16,000 stations. None of the scenarios in *Technical Report Fourteen* projected volumes of CNG use this large (estimates ranged from 40,000 bpd to 546,000 bpd gasoline equivalent). Assuming 400,000 bpd gasoline equivalent of CNG were used, which is far more than projected in most of *Technical Report Fourteen* scenarios, the analysis of the Technical Report would indicate that around 9,450 stations would be required. At a cost of $320,000 per station, the total station conversion costs would be $3.02 billion.

LPG Stations

DOE's Alternative Fuel Data Center estimated there are about 4,800 LPG refueling stations in the U.S. in 1998 (see Figure 18). LPG can be dispensed and sold using systems very similar in appearance to those used for gasoline, and it is assumed that LPG would be sold in this manner in the future when volumes are large enough to support selling LPG at gasoline retail facilities or in facilities dedicated to selling LPG for vehicle use.

The 1992 DOE contractor's report on LPG infrastructure[58] also evaluated the necessary availability of refueling sites. It assumed that the typical high-volume stations dispensing 150,000 gallons per month of gasoline would install LPG capacity and that these would each sell LPG equal to one-third of its total volume or 50,000 gallons per month gasoline equivalent (69,000 gallons of LPG). Thus, each would displace one-third of its gasoline throughput or 50,000 gallons per month of gasoline. The study derived typical station configurations and estimated costs for installing the LPG capability on a per station and national basis. The total

[58] *Assessment of LPG Infrastructure for Transportation Use, supra.*

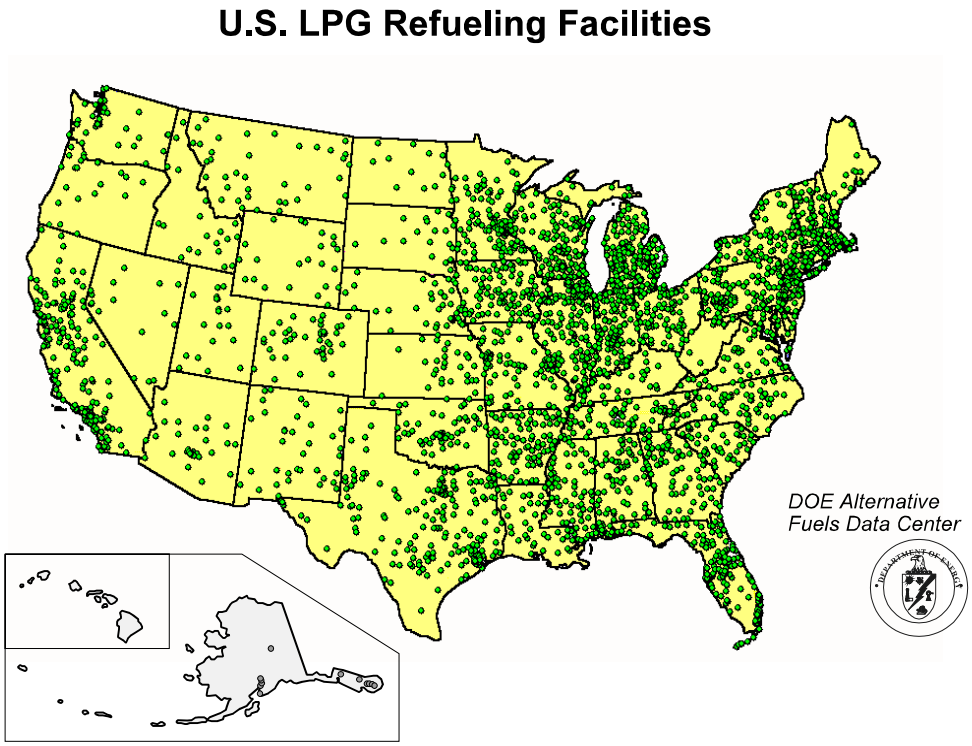


Figure 18. LPG Refueling Facilities in 1998

fuel displacement estimated by the 1992 study was 13.7 billion gallons per year or 655,300 barrels per day gasoline equivalent, including heavy-duty vehicles refueling at truck stops and school buses being refueled at private facilities, each of which had a different estimated cost structure.

Using this displacement target, being met completely by light-duty motor vehicles at ordinary commercial service stations and assuming the per station 50,000 gallon gasoline displacement per month (39 barrels per day), 22,205 such stations would be required to dispense LPG to reach the volume projected by *Technical Report Fourteen*'s 30 percent replacement fuel use scenario (866,000 barrels per day gasoline equivalent). This compares with 12,537 such stations estimated by the 1992 study itself, along with the truck stops and school bus refueling sites.

The incremental cost of installing LPG infrastructure at the existing stations estimated by the 1992 study was $192,800 per station. Applying this cost estimate toward the 22,205 stations estimated to be necessary to reach *Technical Report Fourteen* fuel displacement target (in the 30 percent total replacement fuel scenario) gives a total estimated cost of refueling infrastructure of $4.3 billion.

Electric Vehicle Recharging Stations

Electric vehicle recharging is expected to be performed primarily overnight at the home of the vehicle owner or at fleet facilities for fleet electric vehicles. However, there is also strong interest in providing public recharging facilities at commuter parking lots, shopping malls, and other public facilities where EVs would be partially recharged during the day. Electric utilities are likely to provide substantially lower rates for nighttime recharging as electric demand and capacity usage is lowest then. Some additional charging stations might also be provided to extend the range and flexibility of use of electric vehicles, including metered outlets in parking lots and work places. Most normal driving use would only partially discharge electric vehicles batteries over the course of a day so that overnight recharging would be an option for many motorists. Commercial recharge facilities would probably be priced higher to cover the higher daytime rates, even higher costs for fast-charge equipment and additional charges for facility use. Electric vehicles are not, in the near future, likely to be an option for motorists without individual parking facilities of some sort, for those using vehicles heavily at night, or for extended highway driving.

Installation costs for a recharging unit at a typical home are estimated in DOE's Technical Report at $400-$600.[59] Commercial fleet station costs would be the same except that fleets would be more likely to install a 50 amp outlet for somewhat faster charging at an additional $30 to $90. Private households would also have the option of the 50 amp charging for additional cost. *Technical Report Fourteen* projects a total population of approximately 2.5 million electric vehicles in 2010 (all of which would be required for environmental programs). Assuming that greater numbers of charging stations than vehicles were required might support an estimate of 4 million charging stations. Using a median of the cost estimates of $500, the total cost of the charging infrastructure would be approximately $2 billion.

[59] This is the estimated cost of a 240 volt branch circuit plus a safety device and load management device. The actual battery charger would be installed on the vehicle and forms part of the vehicle cost.

VII. KEY ISSUES AND PERSPECTIVES

As can be concluded from the previous sections, a great deal of uncertainty attends many aspects of increasing the use of alternative/replacement fuels in the U.S. transportation market. Additional information needs to be collected and analyses performed that are critical to evaluate associated implementation policies that are designed to achieve the replacement fuel goals. In some cases, meaningful answers may be obtained only through future experience with AFV and replacement fuel use. DOE continues to collect information and perform analysis that will be able to better address some of these questions. Among the many unanswered questions are the following:

- What will be the cost of establishing infrastructure to distribute and retail alternative fuels? What portion of this cost is truly incremental and what portion represents a necessary expansion of capacity (to meet future transportation vehicle demand) that would have to be made irrespective of whether alternative fuel or conventional fuel were used?

- What market interactions would occur at various stages of alternative fuel infrastructure development and what role should government take to smooth the way?

- What impacts would widespread use of alternative fuels for transportation have on other uses for those fuels?

- What roles could replacement fuels and AFVs play in contingency planning and responses to potential oil shocks? To what extent could capability for fuel switching be a substitute goal for actual alternative fuel use? What value is there to diversifying the fuel needs of critical transportation functions to use domestic fuels that are less subject to petroleum shortages and price spikes?

- Should conservation measures such as high fuel economy vehicles be counted towards achieving the EPACT replacement fuel goals? If so, how would high fuel economy AFVs be counted toward the EPACT replacement fuel goals?

- In a future U.S. market with substantial alternative fuel use, how much of the alternative fuels would be imported and how much produced domestically? How much shifting of energy imports from the transportation sector to other sectors would there be? How much value to U.S. energy security would there be from a multi-fuel transportation sector if the non-petroleum fuels used did not result in a substantial net reduction in energy imports? What policies might be adopted to favor domestic sourcing and should they be pursued?

- Should energy policies such as EPACT be coordinated more closely with environmental policies such as EPA's Clean Fuel Fleet Program?

- Should additional value be placed on alternative fuels with low greenhouse gas emissions?

- What is the realistic maximum potential for use of replacement fuels in blends with conventional petroleum fuels?

- If incentives are used to replace mandates, which ones should be considered and for how long?

- Should tax incentives similar to those for ethanol be extended to biomass-derived replacement fuels in blends with conventional diesel fuel?

- How should incentives take into account differing levels of technological development and market maturity?

- What would be an appropriate level of replacement fuel penetration to safeguard critical transportation functions and mitigate the impacts of petroleum shortages and price spikes?

In the paragraphs that follow, some additional areas calling for further investigation are introduced along with some perspectives.

Fleet to Household AFV Spillover

It is possible to identify a number of ways in which widespread fleet AFV usage could facilitate household AFV use and reduce impediments to it. Large numbers of fleets using AFVs could provide sufficient critical mass for development of alternative fuel distribution and refueling infrastructure, including commercial stations available to the public. They could provide impetus for further technological development and for original equipment manufacturers to offer a wider range of AFV models with more options and on more attractive terms than currently available. Widespread fleet AFV use could also demonstrate to the public the viability of using alternative fuels and the advantages of such use including energy security, environmental, and, in some cases, economic advantages. But these effects may not be sufficient to spur substantial AFV acquisition by the public.

Experience of other countries (Netherlands, New Zealand, and Brazil), as well as DOE modelers,[60] suggests that spillover will, at the initial stages of a transition, occur only if a significant and discernible economic incentive exists for households to purchase AFVs and to use alternative fuels. Currently, all AFVs are more expensive to own or operate than conventional vehicles, except for vehicles such as taxis using natural gas where the lower fuel cost pays for the incremental vehicle cost because of the high number of miles they travel per year. Currently most OEM AFVs are dedicated rather than dual-fuel, which will inhibit their acquisition by households until refueling infrastructure is quite widespread (to enable long-

[60] Leiby, Paul and Jonathan Rubin, 1998. "The Alternative Fuel Transition: Draft Final Results from the TAFV Model of Alternative Fuel Use in Light-Duty Vehicles 1996-2010," February 27, 1998. A final report is expected in May 2000.

distance travel) and concerns about the permanence of its availability have been erased. Electric vehicles' costs and range limitations probably limit their role to a very small segment of the market for the foreseeable future.

Market research suggests that behavior of U.S. households in regard to AFVs will not be qualitatively different from that of the other countries which have promoted transitions.[61] Surveys of U.S. vehicle consumers show that most place high value on range and on fuel availability, but also on emissions reduction. Targeting levels for these three factors in the survey at levels likely to prevail during a transition, the survey indicated that the average consumer would require substantial price discounts in order to purchase an AFV. With fewer than 50 percent of stations dispensing the alternative fuel, less than 250 miles in driving range, or less than a 65 percent emissions reduction, the discount would have to be over $2,000 per vehicle. In order to be purchased at prices equivalent to conventional vehicles, the AFVs must have ranges of at least 300 miles, reduce emissions by 90 percent, and fuel must be available at 80 percent of all service stations in the driving area, according to respondents. While such survey data often diverge from actual purchase decisions, particularly after consumers have had time to familiarize themselves with and analyze the decision factors, the survey may be the best available indication of consumer preferences. It seems clear, at least in regard to dedicated vehicles, that consumers will have to be confident not only that AFVs will become a permanent feature of the automotive market, but also that a particular vehicle/fuel combination will be available five, ten, or even fifteen years in the future.

Fuel Neutrality of Policy Options

The CRS studies summarized in section IV showed that different alternative fuels would have different optimal policy mixes, costs, and energy security and environmental benefits. Recognizing that the different fuels face different mixes of relative obstacles and have different optimal sets of policies for overcoming the obstacles, it might be inferred that policy approaches that are nominally fuel neutral, actually favor certain fuels more than others.[62] For example, generous AFV purchase incentives such as the maximum $2,500 tax deduction provided by EPACT benefit natural gas vehicles more than alcohol vehicles because the incremental cost of the alcohol vehicle is substantially less than the allowable deduction. In addition, the incentive is greater for dedicated than dual-fuel vehicles, and no dedicated alcohol vehicles are currently being offered for sale. Similar differential effects could apply to incentives for infrastructure

---

[61] See Mintz, Marianne, and Singh, Margaret K., op cit., Appendix B, citing Golob, T., et al., Institute of Transportation Studies, University of California, presented at the Electric and Alternative-Fuel Vehicle Demand Forecasting Project Workshop, Laguna Beach, CA, (Nov. 4-5, 1993).

[62] On the other hand, certain measures which might have indirect effects favoring some fuels over others would still have to be considered fuel neutral by virtue of their nature as measures of general application. For example, fuel economy improvements that are not fuel-specific (weight or friction reductions, etc.), whether or not policy induced, could be seen as favoring those fuels which are more expensive on a per-mile basis than gasoline and penalizing fuels that are less expensive than gasoline.

installation and for investments in production facilities. Moreover, the CRS studies show that equal outcomes have unequal costs and vice-versa. This is not to suggest, however, that it would be impossible to devise incentive policies that are truly neutral between the different alternative fuels. Excise tax incentives on an energy equivalent basis would seem to be neutral by reasonable measures. Whether such policies would be sufficient to meet EPACT goals or whether more directed policies will be called for is a question that may have to be addressed at some point.

AFV Technology and EPACT Timetables

Some AFVs have attained a very high level of technical maturity in terms of vehicle driveability and emissions, but most lag behind conventional vehicles in attributes important to vehicle owners such as operating range. The auto manufacturers and other interested parties are continuing development of these AFVs and improvements should be forthcoming. However, the current deficiencies of AFVs in terms of operating range and refueling station availability are discouraging potential owners from purchasing AFVs. A market failure of AFVs at this early stage of EPACT implementation would make acceptance of more advanced AFVs such as fuel cell vehicles more difficult and delay or completely forgo the benefits advanced AFVs offer. However, a strategy of waiting for more advanced AFVs before implementing EPACT would likely result in little or no AFV penetration in the interim and delay infrastructure development further into the future.

Macroeconomic Impacts[63]

It is now generally accepted that oil shocks precipitate reductions in economic activity. In seven of the ten years since 1910 when real oil prices increased more than 25 percent, recessions occurred in the following year (Figure 1, page 16). In addition to the direct impacts of the price increases, abrupt changes in vehicle technologies have followed the price shocks. These abrupt technology changes have adverse impacts on vehicle sales and aggregate economic activity for several years. While *Technical Report Fourteen* estimated the equilibrium benefits of 30 to 40 percent alternative fuel use at approximately $10 billion dollars annually, it did not include the economic benefits of avoiding an oil shock or recession, which could be much greater. These can be calculated in two ways. The first treats the diminished economic activity as temporary, with the economy subsequently making up for lost time and reaching the same level of economic activity as it would have reached without the recession within about a three year interval. In the second scenario, the economy simply resumes the rate of growth it would have experienced without the recession but never makes up for the losses. Assuming a 2.5 percent full employment growth rate and a recession starting with a 1.5 percent shortfall from this natural growth rate in its first year, a 3 percent shortfall in year two, and a 1.5 percent shortfall in year

[63] Discussion drawn largely from *Macroeconomic Implications of Transition to AFV Use*, Danilo Santini, Argonne National Laboratory, background paper prepared at the request of DOE.

three, the magnitude of the economic loss can be envisioned.[64] Under the temporary loss scenario, the loss of economic activity would be $600 billion dollars over three years. Under the permanent loss scenario, the losses would be about $3 trillion over 15 years, using a discount rate of 10 percent.

Impact of Oil Price Cycle on Transition to Alternative Fuels

While EPACT provides a number of specific mechanisms for promoting AFV use by fleets, reaching substantial levels of replacement fuel use will depend on penetration into the motoring public—the household vehicle sector. The key to this penetration will be some economic incentive to households to make the shift. Such an incentive might occur in any one of a number of ways. It would not necessarily have to represent a Government incentive program. Increasing petroleum prices could well imply shifts in relative prices between gasoline and a number of alternative fuels, resulting in natural fuel switching if the preconditions for such switching are in place.

Such potential fuel switching could help mitigate the effects of the oil price spike and reduce the magnitude of the spike. Indeed, a major goal of EPACT is to help prevent future oil crises or mitigate their effects. Nonetheless, future movements in oil prices, including erratic movements, can be expected. To the extent that current price relationships inhibit the actual immediate use of alternative fuels, policies to establish preconditions for fuel switching in future situations could partially substitute for immediate alternative fuel use and might play similar preventive roles.

Investigation of historical crude oil prices, indexed for inflation, shows a somewhat consistent pattern from early in this century to the present: a "sawtooth" with periodic sharp abrupt rises followed by more gradual and prolonged downward trends lasting two to two-and-a-half decades (sometimes including erratic movements within these downward trend periods). This pattern is presented in Figure 1 (page 16). As can be seen from Figure 1, crude prices have been on the downward part of the cycle since the early 1980s, suggesting that, if history is a guide, another significant price spike might be expected in the next seven to fifteen years.[65] Current empirical evidence could be seen as consistent with this. Economic growth in Asia has been accompanied by growth of energy use, which could be outstripping growth of world oil production, and could

---

[64] These GNP loss assumptions appear to be consistent with estimates using 14 major economic models to predict the effects of a 50 percent oil price shock sustained indefinitely. The average estimates for economic losses were 1.8 percent in the first year, 2.7 percent second year, 2.5 percent third year and 2.3 percent fourth year. Energy Modeling Forum, "International Oil Supplies and Demands," EMF Report 11, Vol. II, April 1992, Stanford University. See also Greene, David L., and Leiby, Paul N., "The Social Costs to the U.S. of Monopolization of the World Oil Market, 1972-1991," Oak Ridge National Laboratory, March 1993, ORNL-6744, pp. 35-40.

[65] The oil price jolt of late 1989 following the Iraqi invasion of Kuwait does not represent a major upward price movement according to this pattern, but only part of an erratic downward trend since 1982 or so. The last major upward jump encompassed the 1973-74 oil crisis and the 1979-82 oil shock.

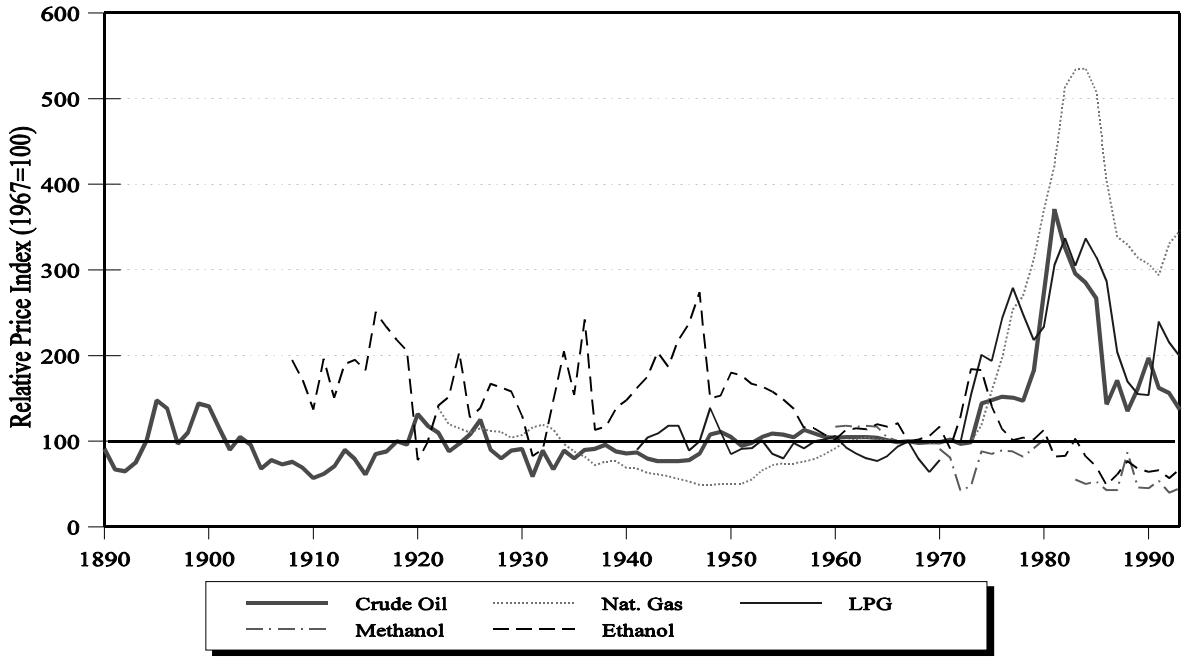


Figure 19. Relative Wholesale Prices for Fuels/Raw Materials
Compiled by Danilo J. Santini of Argonne National Laboratory

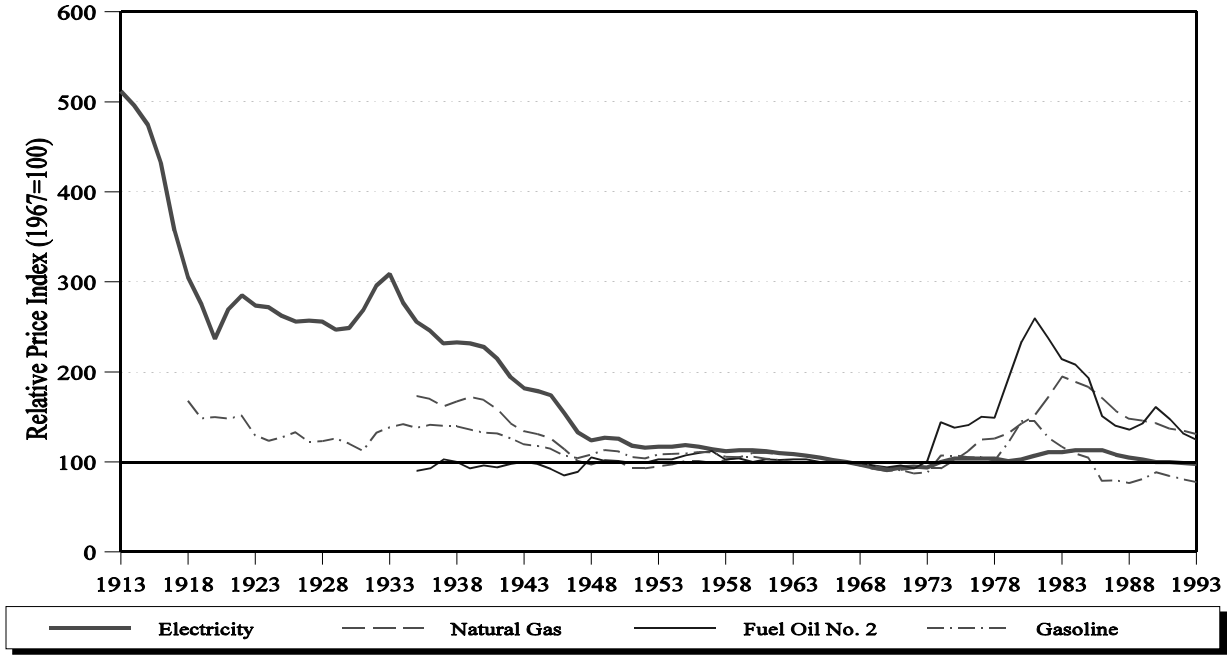


Figure 20. Relative Consumer Energy Prices, Fuel and Electricity Prices
Compiled by Danilo J. Santini of Argonne National Laboratory

lead to tight market conditions in the seven to fifteen year time frame. Various observers have also pointed to underlying conditions that could give rise to political instability in major oil producing countries in the same time period.

Historical movements in prices for alternative fuels and feedstocks relative to petroleum are shown in Figure 19 and Figure 20. Crude oil, natural gas, methanol, ethanol, and LPG are included in Figure 19 (wholesale price data). Electricity is included in Figure 20 along with gasoline, natural gas, and fuel oil no. 2 (consumer price data). The most clear divergences in relative price movements from gasoline and crude oil are for methanol, ethanol, and electricity. As can be seen, although electricity and ethanol prices are influenced by the jumps in oil prices, the resulting price increases for these forms of energy are not nearly of the same degree as for oil. Methanol prices have historically moved independently from petroleum prices. Natural gas prices seem to have moved largely independently of oil prices during the post-war period through 1960, but have moved in close lock-step with them since that time. This is due to the substitutability of natural gas and petroleum fuels in many non-transportation applications and to the deregulation of natural gas prices in the mid- to late-1970s.[66]

Moreover, in the event of an actual oil crisis with real shortages and gas lines, consumer convenience factors could shift decisively in favor of alternative fuels. Rather than requiring a price premium for switching to alternative fuels, motorists might well be willing to pay a premium for the option of refueling with a fuel less susceptible to shortages. This effect might transcend the period of actual oil shortage for a period of some years thereafter while the sense of insecurity persists.

There is probably no way of reliably assessing the impact of a future price hike on the effectiveness of EPACT programs. On the other hand, it does appear possible to infer from prior experience that such a hike is unlikely to result in major fuel switching in the transportation sector in the absence of certain preconditions relating to the availability of AFVs and alternative fuel infrastructure, which EPACT title V begins to address. It should be noted that most of the fuel switching in Brazil and the Netherlands, the two countries where AFV programs were most effective, occurred after an oil shock that had been preceded by more modest programs promoting the alternative fuel to which the country partly switched after the shock.

Impact of EPACT on Potential Oil Crises[67]

Intuitively, it would be more desirable to have a slow rise in oil prices supporting efficiency enhancing or fuel switching efforts already underway rather than to have a sharp rise in oil prices cause belated and hurried implementation of technologies that could technically have been introduced before the shock. The historical record, however, does not give any comfort that the U.S. will have the option of such gradual and presumably efficient substitution. EPACT is a

---

[66] Future prices of any fuel(s) that come into widespread use in light-duty vehicles could be expected to move more closely with gasoline/crude oil but this would occur mainly after the fuel had gained a competitive advantage. Ample divergences in price movements could remain.

[67] Ibid.

unique piece of Federal legislation in that it provides incentives to restrain rising oil demand before it leads to run-up in oil prices of the nature of those highlighted in Figure 1 (page 16). Provisions of the Clean Air Act Amendments, including gasoline reformulation, also have the effect of displacing crude oil from gasoline, potentially preventing some of the pressure for a rise in oil prices. Whether these effects will be powerful enough to prevent a future world oil price run-up is far from clear.

EPACT programs could also reduce the likelihood or magnitude of a future oil shock in another way. One potential benefit of developing a fuel switching capability is the potential to alter the behavior of primary fuel suppliers. If viable competing fuels are available, the likelihood of an oil supply shortage and a run up in oil prices will be diminished. Since OPEC members know the long-term consequences of a spike in oil prices are subsequently declining and depressed prices, they should give strategic consideration to how high prices can go and how long they can be sustained before causing the introduction of substitutes and conservation. In fact, some OPEC members have been known to base their positions on pricing and production on just such considerations. EPACT has the potential to lessen the impact of an oil price shock in the key transportation sector, precisely the sector where alternatives to oil are least available. The better the perceived potential of the U.S. to introduce alternatives in the event of an oil price increase, the less the likelihood and/or magnitude of the price increase likely to be sought by OPEC members in the event of a supply disruption.

This deterrence effect, of course, assumes that OPEC member governments are rational actors in control of crude oil pricing and production within their respective countries. The deterrence might be less effective in the event of some major instability in one or more of the major oil producing countries.

It is also possible that a well designed EPACT initiated process of fuel switching could avoid or reduce the magnitude of problems involved with the relatively abrupt technological transitions in transportation that historically follow oil shocks and that have also characterized historical fuel switches. Alternative fuel technologies are considered more developed at the present than other transportation and energy-related technologies have been, due in part to DOE RD&D programs. Alternative fuel transportation systems could be even riper for widespread deployment, and the American public could be more amenable to fuel switching if EPACT programs, in concert with significant alternative fuel incentives, are able to increase alternative fuel infrastructure and AFV availability.

DISCLAIMER

This document highlights work sponsored by agencies of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that it would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Printed on recycled paper